GROUND WATER

IN

NORTH-CENTRAL PENNSYLVANIA

STANLEY W. LOHMAN

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GROUND WATER

IN

NORTH-CENTRAL PENNSYLVANIA

By

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With Analyses by
E. W. LOHR

(Prepared in cooperation between the United States Geological Survey and the Pennsylvania Topographic and Geologic Survey)

DEPARTMENT OF INTERNAL AFFAIRS
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By Stanley W. Lohman

ABSTRACT

This report describes the geography, geology, and ground-water resources of an area covering 7,221 square miles in north-central Pennsylvania, including the 8 counties of Bradford, Cameron, Elk, Lycoming, McKean, Potter, Sullivan, and Tioga. Many previously published geologic reports, particularly those of the Second Geological Survey of Pennsylvania, were freely used in the preparation of this report. The hydrologic information was obtained in the field in 1935, chiefly by interviewing well drillers and owners of private, industrial, and public water supplies. Considerable time in the field was devoted to the study of the water-bearing formations, particularly the glacial lake and stream deposits, which are the most productive sources of ground water.

The area is well endowed with natural resources. Some coal has been mined in each county from the Pennsylvanian formations, but the principal output of coal in the area comes from Elk County. There are numerous shallow oil and gas fields in the northwestern part of the area, including the famous Bradford field, and in recent years large volumes of gas have been discovered in the deeply buried Oriskany sand in Potter and Tioga Counties. Only about 34 percent of the total land area is devoted to farming, but dairying is an important industry in the northeastern part of the area.

Most of the area lies in the Appalachian Plateau province where the strata are nearly horizontal, but about half of Lycoming County lies in the Valley and Ridge province where the strata have been severely folded. The area is quite hilly, and large areas are heavily forested. The maximum relief is about 2,113 feet, and the local relief is more than 1,000 to 1,800 feet in some places. The area lies in three major drainage basins, which are, in order of their size, the Susquehanna, Ohio, and Genesee. Important drainage changes that occurred during the Tertiary and Pleistocene are discussed in some detail, as they have had an important bearing on the ground-water resources.

More than half of the area has been glaciated two and possibly three times, and many of the main valleys both north and south of the glacial borders were occupied by glacial lakes during the Pleistocene. Deposits of sand and gravel laid down in these lakes and along the flooded streams that emanated from the melting glaciers are by far the most productive sources of large quantities of ground water in the area. For this reason a map showing the areal extent of these deposits has been included. The consolidated rocks exposed in the area are of Ordovician, Silurian, Devonian, and Carboniferous age. The Ordovician and Silurian strata and a large part of the Devonian strata are exposed only in Lycoming County, all of the other counties being underlain by Devonian and Carboniferous strata. The youngest rock formation preserved from erosion is the Conemaugh. The sandstones of the Carboniferous system are very productive in the western part of the area, being second only to the glacial sand

and gravel deposits. The history of deposition and the character and water-bearing capacity of all the geologic formations are described.

The source and occurrence of ground water are described, together with the water-bearing properties of the different types of rock. The fluctuations and behavior of the water table are discussed, and illustrated by the hydrographs of 6 observation wells located in different parts of the area. The principles governing the recovery of ground water by means of dug, driven, and drilled wells, springs, and infiltration galleries are described, together with the types of pumps in use in the area. Particular emphasis is placed on the use of screens in wells ending in sand or gravel, the importance of which has not been fully realized by many well drillers and owners. The utilization of ground water for domestic, industrial, or public supply in the area is described. Considerable ground water is used by many industries, especially for cooling—the average temperature of ground water from measurements of 46 representative wells being 51° F. Large quantities of ground water are also used in the Bradford oil field for repressuring the oil sands by the "water flood method." The industrial water supply of a paper company at Johnsburg, Elk County, is described in some detail as it is one of the largest industrial ground-water developments in the State. Of 52 public water supplies in the area, 25 use ground water exclusively, 14 use ground and surface water, and 13 use only surface water.

The analyses of 41 samples of ground water are given, together with discussions of the principal chemical constituents of the waters in relation to the use of water, and in relation to their geologic occurrence. A summary table is given showing the range in concentration of the principal mineral constituents in waters from the different geologic formations. Most of the ground waters in the area are satisfactory for most purposes, but some contain considerable iron, some are brackish or salty, and some are sufficiently hard as to require softening for certain purposes. Methods of treating water for the removal of iron and the reduction of hardness are briefly discussed.

The local geography, geology, and ground-water conditions are also described in separate sections for each county, including descriptions of the public water works that use ground water. Tables of analyses and of well and spring records are given in each county section, together with the logs of a few of the wells.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report describes one of the six areas into which the State of Pennsylvania was divided for the systematic investigation of its ground-water resources by the Pennsylvania Topographic and Geologic Survey in cooperation with the Geological Survey, United States Department of Interior. The principal purpose of this investigation has been to provide accurate information as to the sources of ground water throughout the State, and as to the quantity, quality, and methods of recovery of these water supplies, in order that any individual, industry, or municipality may find the basic information necessary for a satisfactory and economical solution of its problems in regard to water supplies from wells or springs.

LOCATION AND EXTENT OF THE AREA

The area described in this report lies in the north-central part of Pennsylvania and embraces 7,221 square miles. It includes the following 8 counties: Bradford, Cameron, Elk, Lycoming, McKean, Potter, Sullivan, and Tioga. The area lies between meridians 76°07′ and 79°06′ west longitude and between parallels 41°05′ and 42° north latitude. The location of the area with respect to the boundaries of the State and to the other five units of the State-wide ground-water survey in order studied is shown in figure 1.

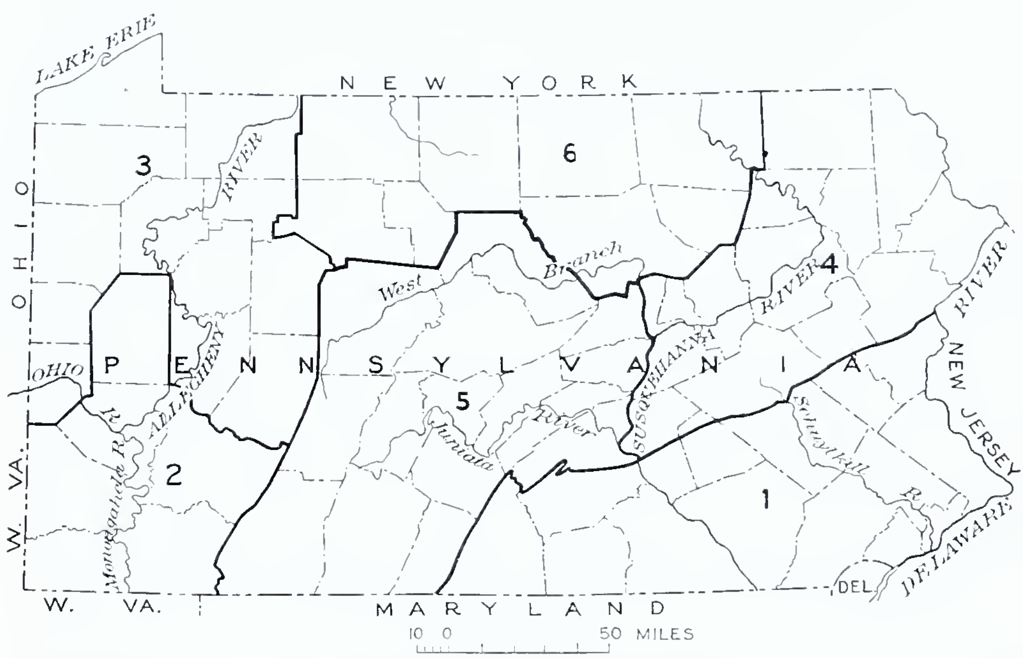

Fig. 1. Index map of Pennsylvania, showing areas covered by ground-water reports of Pennsylvania Geol. Survey, 4th series: 1. Southeastern Pennsylvania, Bull. W 2; 2. Southwestern Pennsylvania, Bull. W 1; Northwestern Pennsylvania, Bull. W 3; 4. Northeastern Pennsylvania, Bull. W 4; 5. South-Central Pennsylvania, Bull. W 5; 6. Area covered by this report, Bull. W 6.

FIELD WORK

The field work for this report was done in the summer of 1935. Records were collected of more than 700 wells and springs that furnish municipal, industrial, and domestic supplies, and well owners and drillers were interviewed. Only those village, borough, and city water supplies were investigated that are derived from ground water, no study being made of those using water from streams or lakes. Considerable time was devoted to the study of the water-bearing formations, especially the glacial lake and stream deposits, which are the most productive sources of ground water. Samples of water from 41 representative wells and springs were analyzed in the water-resources laboratory of the Federal Geological Survey by E. W. Lohr.

The work was carried on under the supervision of G. H. Ashley, State Geologist of Pennsylvania, and O. E. Meinzer, geologist in charge of the division of ground water of the Geological Survey, United States Department of the Interior. The manuscript of this report received the constructive criticism of O. E. Meinzer, W. D. Collins, W. C. Alden, G. W. Stose, and G. B. Richardson, all of the Geological Survey, and of G. H. Ashley, R. W. Stone, and Bradford Willard of the State Survey.

PREVIOUS INVESTIGATIONS

The Second Geological Survey of Pennsylvania published reports from 1878 to 1885 on the geology of all the counties within this area, and these reports were later summarized by J. P. Lesley, State geologist, in the summary final report of the Second Geological Survey. Much of the geologic data here presented were taken from these reports and maps, which contain a wealth of information on the geology of the area. Later reports, chiefly those of the Pennsylvania Topographic and Geologic Survey and the United States Geological Survey, have also been consulted and are listed in the bibliography and acknowledged by footnotes throughout this report.

As a basis for locating wells and studying the geologic and hydrologic features of the region, the topographic maps of the United States Geological Survey were used so far as available. However, no topographic maps were available for Cameron County, more than half of Bradford, Elk, and Potter Counties, and parts of the other counties, and in these areas the tactical maps of the Corp of Engineers, U. S. Army, were used. Base maps of the Galeton and Hoytville quadrangles compiled from aerial photographs and ground surveys by the Pennsylvania Department of Forests and Waters were also used.

The tactical maps were compiled mainly from old county road maps and are inaccurate in many respects. Hence locations based on these maps may be somewhat in error. Locations based on the topographic maps are believed to be correct, and may be distinguished in the tables of well records by the fact that altitudes are given for these locations.

In the following bibliography no attempt has been made to list all of the reports that touch upon the geology of the area, but merely to list those geologic reports, most of which contain areal geologic maps, from which most of the descriptions of geologic formations or structures were taken and which furnished the basis for determining the geologic horizons of the water-bearing beds in wells. The list also includes a few reports dealing with ground-water conditions in the area.

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This report would not have been possible without the cooperation of well drillers and well owners throughout the area. The writer is particularly indebted to the following persons who contributed valuable information regarding ground-water conditions in different parts of the area: M. J. Barrick, district engineer, and R. S. Mark, assistant, Pennsylvania Department of Health, Williamsport; Mr. Warner, Forest Oil Co., Bradford; Kenneth Meyers, Petroleum Reclamation Corp., Bradford; Captain E. B. Chase, Chief engineer, Williamsport Water Co., Williamsport.

GEOGRAPHY

PHYSICAL DIVISIONS

The physical divisions represented in Pennsylvania are shown in Figure 2.

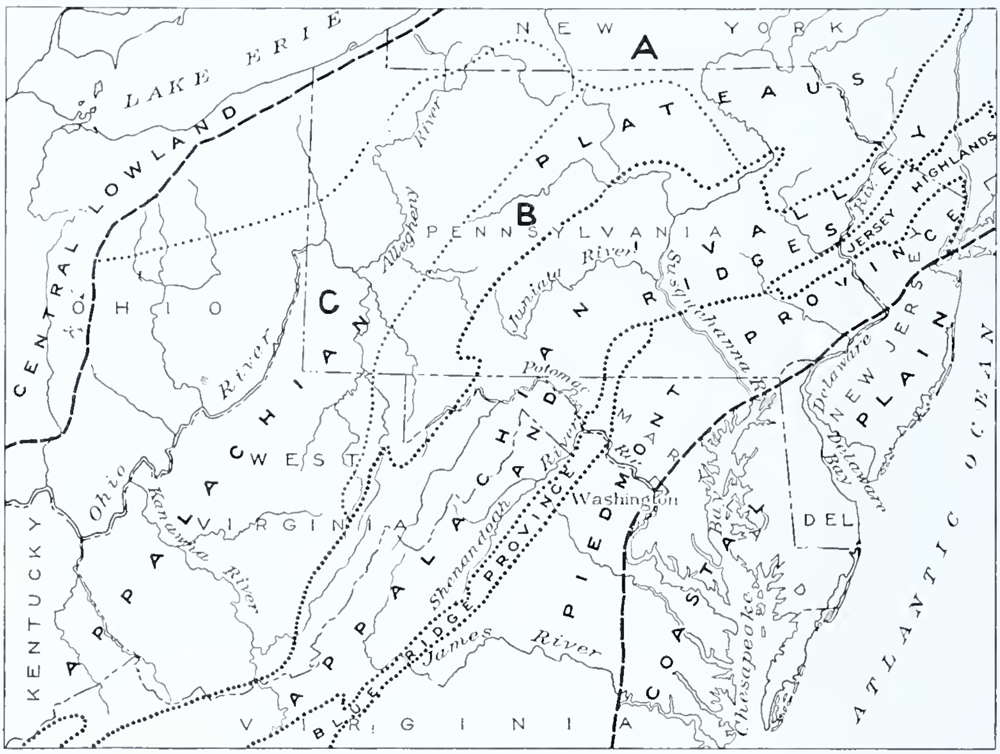


Fig. 2. Map of Pennsylvania and adjacent states showing the major physical divisions (after Fenneman). Subdivisions of the Appalachian Plateaus province: A, Allegheny Mountain section; B, Southern New York section; C, Kanawha section.

Differences in topography, rocks, and geologic structure form the basis for a natural subdivision of the Appalachian Highlands into several provinces.[1] The area described in this report lies within two

[1] Fenneman, N. M., Physiographic divisions of the United States, 3rd Ed.: Annals, Assoc. Am. Geographers, vol. 18, no. 4, 1928.

of these provinces, the Valley and Ridge province (sometimes called the Valley and Ridge section of the Appalachian Valley province) and the Appalachian Plateaus province. The boundary between these two provinces is a striking escarpment called the Allegheny Front, which in this area is known from west to east as Short Mountain, Allegheny Ridge, and North Mountain. A view of that part of the Allegheny Front known as Allegheny Ridge is shown in Plate 3A.

That part of the area lying south of the Allegheny Front, comprising about half of Lycoming County and a small area in Sullivan County, lies in the Valley and Ridge province. This province comprises an alternate succession of narrow ridges and broad or narrow valleys trending east or northeast. Geologically this is a region of alternating hard and soft sedimentary rocks that have been severely folded by lateral compression from the southeast into a series of crests and troughs. After the rocks had been folded the whole area was slowly base-leveled by erosion, and hard and soft layers alike were finally reduced to a nearly uniform surface. There followed a general uplift of the region that gave the streams renewed vigor and began another period of erosion which has continued to the present time. As a result of this last cycle of erosion the softer rocks have been eroded away leaving valleys such as that of Bald Eagle Creek and the West Branch of the Susquehanna River, and the more resistant rocks stand out as long, narrow, even-crested ridges such as Bald Eagle Mountain and North White Deer Ridge, in southern Lycoming County.

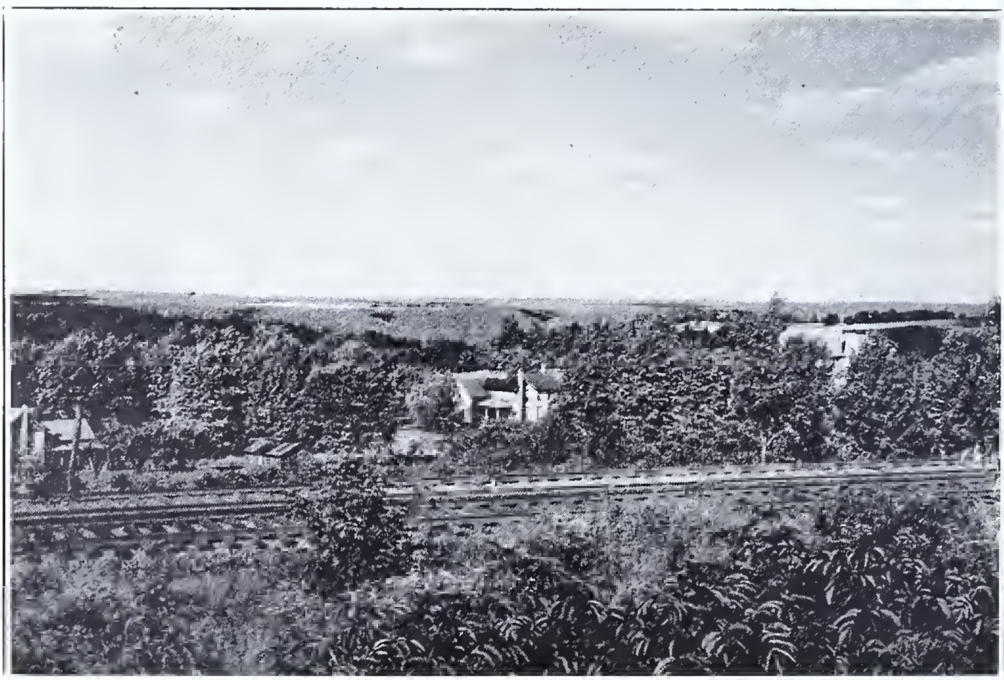
The remainder of the area lies in the Appalachian Plateaus province, where, in contrast to the Valley and Ridge province, the strata have been disturbed but slightly from their original altitude, and lie nearly horizontal in most places. The essential features of this province are those of a dissected plateau. Several sections of the province are distinguished by altitude, degree of dissection, degree of rock folding, or presence or absence of glaciation. Thus the topography in that part of the area lying in the Allegheny Mountain section is affected by open folds. The Southern New York, or glacial section, is separated approximately from adjacent sections to the south by the southern limit of the last or Wisconsin stage of glaciation. Actually the ice advanced somewhat farther south than the boundary of the glaciated section shown in figure 2. The northwestern part of the area lies in the Kanawha section, also called the Allegheny High plateaus. This section is a high, maturely dissected plateau in which wide expanses of the eroded ancient surface still may be seen, as shown in Plate 3B.

RELIEF

In that part of the area that has been mapped topographically the greatest relief is found in the Allegheny Mountain section in Lycoming and Sullivan Counties, where several tributaries of the West Branch of the Susquehanna River have cut deep gorges to depths of 1,000 to more than 1,800 feet below the southern escarpment of the plateau. The maximum relief in each county exceeds 1,000 feet, and is more than 1,800 feet in both Lycoming and Sullivan Counties.

PLATE 3

A. Allegheny Front. Looking north across the Susquehanna River, up the valley of Loyalsock Creek, Lycoming County.



B. Appalachian Plateau. Looking north from Mt. Jewett, McKean County.

The highest known point in the area is an unnamed peak on North Mountain in southern Sullivan County, which rises 2,593 feet above sea level, and 1,813 feet above Muncy Creek which flows through a gorge only 2 miles west of the peak. On the topographic map of the Gaines quadrangle, Tioga County, surveyed in 1899, the east half of a hilltop in Ulysses Township at the western margin of the map is shown to stand at an altitude of 2,600 feet, but this appears to be in error as on the recently surveyed Genesee quadrangle which adjoins to the west, the altitude of the west half of the same hilltop is given as 2,560 feet. Several points in central Potter County rise to an altitude of 2,560 feet and a considerable area lies above 2,500 feet.

The West Branch of the Susquehanna River leaves Lycoming County at an altitude of about 480 feet, the lowest point in the area. The difference in altitude between the highest and lowest known points is therefore about 2,113 feet.

DRAINAGE

The area is divided into three major drainage basins, which are, in order of their size, the Susquehanna, Ohio, and Genesee. The eastern continental divide traverses Elk County from south to northeast, passes through the southeast corner of McKean County, and traverses northern Potter County. Along this divide in north-central Potter County, 1.7 miles south of the village of Gold, a flat-topped hill is reached that separates the three major drainage systems. The drainage of a small area north of this point flows through the Genesee River to Lake Ontario and the St. Lawrence River.

The area west of the continental divide, comprising about two-thirds of Elk County, nearly all of McKean County, and about one-fourth of Potter County is drained by tributaries of the Ohio River. The Clarion River drains most of Western Elk County and a small area in southern McKean County. Nearly all of McKean County and all of Potter County west of the continental divide are drained by the Allegheny River which heads in central Potter County.

The remainder of the area is drained by the Susquehanna River. The North Branch of the Susquehanna River drains nearly all of Bradford County through which it flows, and its tributaries drain half of Tioga County and small areas of Potters, Lycoming, and Sullivan Counties. The West Branch of the Susquehanna River drains nearly all of Lycoming County through which it flows, and its tributaries drain all of Cameron County, nearly all of Sullivan County, large areas in Elk, Potter, and Tioga Counties, and small areas in Bradford and McKean Counties.

The more important tributary drainage systems are noted in the county descriptions.

POPULATION

According to the census, the area covered by this report had a total population in 1930 of 293,224, and an average density of population of only 40.6 inhabitants per square mile as compared with 214.8 for the entire State. In density of population Lycoming County leads with 76.6 inhabitants per square mile, while Cameron County is the most

sparsely populated with only 13.5 inhabitants per square mile. Williamsport, with 45,729 inhabitants, is the largest city, and Bradford, with 19,306, is next in size. There are 33 communities that have populations of more than 1,000, and these contain 54.5 percent of the inhabitants of the area.

TRANSPORTATION

The area is served by a dozen different railroads. The Erie Division of the Pennsylvania Railroad follows the West Branch of the Susquehanna River through Lycoming and Clinton Counties and thence through Cameron, Potter, and McKean Counties to Buffalo, New York. Branch lines of the Pennsylvania extend into all counties in the area. The main line of the Lehigh Valley Railroad follows the North Branch of the Susquehanna River through Bradford County, with a branch line extending through eastern Sullivan County. The Erie Railroad has lines in Elk, McKean, and Tioga Counties. The Baltimore & Ohio has lines in Elk, Cameron, McKean, Potter, and Tioga Counties. The New York Central follows Pine Creek through Lycoming and Tioga Counties.

Other railroads serving one or more counties in the area include the Reading, New York & Pennsylvania, Susquehanna & New York, Coudersport & Port Allegany, Williamsport & North Branch, Pittsburgh Shawmut & Northern, Kane and Elk, and the Tionesta Valley (narrow gauge).

The area is fairly well covered by a network of modern highways except in the heavily forested central part of the area. The Roosevelt Highway (U. S. Route 6) traverses the northern tier of counties from east to west. The Buck Tail Trail (U. S. Route 120), which follows the West Branch of the Susquehanna River through Lycoming, Clinton, and Cameron Counties, is one of the most scenic routes in the State. In addition to the Buck Tail Trail, the Susquehanna Trail (U. S. Route 111) and U. S. Routes 219 and 220 are the principal north-south routes of travel across the area. Numerous State and county roads connect the rural regions with one or more of the main routes.

Of special interest is the old Coudersport Pike (Pennsylvania route 44) connecting Jersey Shore with Coudersport and points in New York. Contrary to most of the through routes which follow large rivers or successions of valley areas, the Coudersport Pike throughout most of its length follows the highest part of the plateau, and along certain stretches one can look for miles in all directions over a wild forested country with few signs of habitation.

AGRICULTURE

Only about 34 percent of the total land area in the 8 counties was devoted to farming in 1930. Bradford and Tioga Counties ranked first and second with 75.2 percent and 58 percent of their total land area under cultivation, and Cameron County ranked last with only 8.4 percent.

The principal crops of the area are corn, oats, buckwheat, potatoes, and hay.

Dairying has been for years one of the leading industries in Bradford and Tioga Counties, and is also carried on to a lesser extent in some of the adjoining counties. In 1929 Bradford County ranked third among the 67 counties of the State in annual milk production with 21,508,018 gallons and Tioga County ranked sixth with 15,879,899 gallons. Considerable milk is shipped to New York City and other markets from Bradford and Tioga Counties, and condensed milk and cheese are made at several places.

NATURAL RESOURCES AND INDUSTRIES

North-central Pennsylvania is well endowed with natural resources, including oil, natural gas, coal, timber, clay, limestone, moulding sand, building stone, and sand and gravel.

McKean County is the principal oil-producing county of Pennsylvania. Most of the production comes from the well-known Bradford field in the north-central part of the county, which has been producing since 1864. Before recovery by the water-flood method was introduced the field was considered nearly exhausted, but it has responded so well to this new method of recovery that many more years of production are now predicted. There are several large oil refineries in McKean County, at Bradford, Farmers Valley, and Eldred. Some oil is also produced in Elk and Potter Counties, and at one time oil was produced in the Gaines field of Tioga county.

There are numerous shallow gas fields in McKean, Elk, and Potter Counties, and one in Tioga County, but unlike the oil fields these shallow gas fields have no long assured future.

In September 1930, natural gas in large volume was discovered in north-central Tioga County in the Oriskany sand, at a depth of 4,006 feet, and in November, 1931, a similar discovery was made in Hebron Township, Potter County, at a depth of about 5,000 feet. Since that time there has been considerable deep drilling activity in Potter and Tioga Counties and adjacent areas, and additional production has been obtained in Potter and Tioga Counties. Gas from the Oriskany may be found eventually in some of the other counties in the Plateaus province covered by this report.

Although north-central Pennsylvania as a whole is not an important coal-producing area as compared with the northeastern and western parts of the State, some coal has been produced in each county covered by this report. When the area was visited in 1935, coal was being mined actively only in Elk and Tioga Counties. Operations were expected to resume in the semi-anthracite mines in the Bernice basin, Sullivan County, however, and small amounts of bituminous coal for local consumption were being mined in Lycoming County and probably in some of the other counties.

Limestone is quarried in Lycoming County and to a lesser extent in Elk County. Small quantities have been quarried, principally for burning, in some of the other counties.

Building stone for local use is available in all of the counties in the area, and flagstones are quarried at several places in the eastern counties.

Moulding sand is obtained from Cameron, Elk, Lycoming, and McKean Counties.

Sand and gravel for building purposes are obtained in many places throughout the area, particularly in the glaciated portion and along some of the valleys south of the glaciated area which contain glacial outwash. Material of this kind is shown in plate 11.

Clay or shale are mined and used for making brick and terracotta in Cameron, Elk, and McKean County.

In the early history of the area, lumbering and tanning were very important industries, but at the present time practically all of the timber land has been cut over, much of it having been cut twice or more, and the lumbering industry has nearly disappeared. Practically all of the hemlocks and other conifers have disappeared and in their place are now growing forests of hardwoods. Several shoe-last plants in the area use local maple. Holgate Brothers, in Kane, make wooden toys from local oak and maple. In 1935, 9 tanneries were observed in operation in the area, 3 in Elk County, 2 each in McKean and Tioga Counties, and 1 each in Lycoming and Potter Counties. At one time there were at least 8 chemical plants in McKean and Potter Counties manufacturing acetic acid, acetone, charcoal, and other products from local hardwoods, although in 1935 only 5 of these plants were observed in operation. The largest individual user of local wood in the area is the Castanea Paper Company, at Johnsonburg, Elk County. During dry years, this company is also the largest industrial user of ground water, as described on pages 63-66. Considerable furniture is manufactured in Lycoming County, but it is understood that very little native wood is used for this purpose.

CLIMATE

The average annual precipitation in the area is about 39 inches, ranging from about 34 inches at Wellsboro to nearly 44 inches at Emporium. The greatest annual precipitation on record in the area was 85 inches, at Wellsboro, Tioga County, in 1880, and the smallest annual precipitation on record was 23.92 inches, at the same station, in 1930. The year 1930 was the dryest year on record at most of the rainfall stations in the area.

Although the precipitation is fairly well distributed throughout the 12 months of the year, the heaviest precipitation occurs generally in May, June, July, and August, and the minimum occurs generally in February. Thus the heaviest precipitation occurs during the growing season when it is of the most benefit to crops.

The average annual snowfall ranges from about 36 inches at Williamsport to more than 60 inches on the high plateau in Elk and McKean Counties. Most of the snow falls between November and April inclusive, but traces of snow have been recorded in October and May at most of the stations.

The mean annual temperature ranges from less than 46° F. on the high plateau of McKean County to about 50° F. at Williamsport, Lycoming County. January, with average temperatures of 23° to 30° F., is the coldest month, and July, with average temperatures of 67° to 73° F., is the warmest month. Temperatures as high as 104° F. have been recorded at Williamsport, and as low as –39° F. have been recorded at Lawrenceville, Tioga County. The first killing frost in the fall generally occurs late in September or early in October, and the last killing frost in the Spring generally occurs in the later part of April or in the first half of May. Killing frosts have occurred as early as late August and as late as late June. The average length of the growing season at Williamsport is 176 days, but for the stations on the plateau it ranges from 127 to 155 days.

The chief climatic data for 10 stations in and near the area are summarized in the following table.

Summary of climatic data for 10 stations in north-central Pennsylvania

[From U. S. Weather Bureau]

Station	Altitude above sea level (feet)	Precipitation		Temperature		Average length of the growing season (days)	Snowfall	
		Length of record (years)	Mean annual (inches)	Length of record (years)	Mean annual (°F.)		Length of record (years)	Mean annual (inches)
Ohio drainage								
Kane (near)	2,020	5	40.76	5	45.5	----	----	----
Ridgeway	1,350	32	39.50	22	----	----	----	----
St. Marys	----	----	----	----	----	----	14	60.3
Warren[1]	1,180	48	39.89	43	48.0	139	36	63.1
Atlantic drainage								
Emporium	1,050	50	43.59	50	----	137	41	46.4
Lawrenceville	1,000	40	34.46	40	48.1	127	33	44.5
Muncy Valley	1,045	25	43.12	25	46.6	136	----	----
Towanda	754	43	34.65	43	48.3	155	35	41.1
Wellsboro	1,419	67	33.86	57	46.4	133	40	51.8
Williamsport	521	51	39.10	48	50.4	176	36	36.8

[1] Warren County, not in area covered by this report.

GEOLOGY

SUMMARY OF STRATIGRAPHY

Consolidated rocks.—The consolidated rocks that crop out in the area are of Ordovician, Silurian, Devonian, and Carboniferous age. The older rocks, comprising the Ordovician, Silurian, and Lower and Middle Devonian, are exposed only in southern Lycoming County, in the Valley and Ridge province. The remainder of the area, which is all in the Plateaus province, is underlain by Upper Devonian and Carboniferous rocks.

The oldest rocks in the area, undifferentiated Ordovician limestones and dolomites, crop out only in Nippenose and Mosquito Valleys, in Lycoming County. The youngest Paleozoic formation, the Conemaugh formation of Pennsylvanian age, crops out only in southernmost Elk County.

Since the geologic reconnaissance of the second geological survey of Pennsylvania, the geology of only 4 out of a total of 40 quadrangles covering the area has been re-surveyed on a scale of 1:62,500, of which only 3 have been published. In 1903 geologic folios describing the geology of the Gaines, Elkland, and Tioga quadrangles in Potter and Tioga Counties were published by the U. S. Geological Survey, and the geology of the Bradford quadrangle, McKean County was published by the Pennsylvania Geological Survey in 1938.

The areal distribution of the formations mapped by the Second Geological Survey is shown on plate 1. In the description of water-bearing formations, attention will be called to several discrepancies in the mapping of the Second Survey, notably of the Lower Devonian in Lycoming County and of the Pennsylvanian formations in Potter County. In the present report, the stratigraphic nomenclature of the later reports has been followed in the few quadrangles that have been remapped. Regional descriptions of the consolidated rock formations and the occurrence of ground water in them are given on subsequent pages.

Unconsolidated deposits.—There is evidence that during the Pleistocene epoch the eastern part of the area was subjected to three stages of continental glaciation. The glaciers came from the northeast, and, according to recent work by Leverett,[2] at the times of maximum advance they reached the approximate positions shown on plate 1. The three stages of glaciation in this area are named, in chronological order, the Jerseyan, Illinoian, and Wisconsin. Evidence for the earliest or Jerseyan glaciation and of the middle or Illinoian glaciation is rather scanty and in most places is apparent only to a trained observer. The evidence of the latest or Wisconsin glaciation is clearly recognizable to anyone visiting the area.

[2] Leverett, Frank, Glacial deposits outside the Wisconsin Terminal Moraine in Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G 7, 123 pp., 2 pls. (incl. map), 38 figs., 1934.

The deposits left directly by the melting ice are found mantling the consolidated rocks at many places north of the glacial boundaries shown on plate 1. Of much greater value as reservoirs for ground water, however, are deposits known as glacial outwash which were made by the swollen streams emanating from the retreating glaciers and are now found along many of the larger streams both north and south of the glacial boundaries, and deposits formed in lakes created by the damming of streams by lobes of the glaciers. Deposits of this type are shown in plate 2. The several types of unconsolidated deposits and their water-bearing capacity are discussed under Quaternary system, and in the county descriptions.

A generalized section of the geologic formations of north-central Pennsylvania follows.

General section of the geologic formations in north-central Pennsylvania

System	Series	Subdivisions	Thickness (feet)	Character of material	Ground-water conditions
Quaternary	Recent	Alluvium	0—30±	Clay, silt, sand and gravel.	May supply a few dug and driven wells.
		—Unconformable on older formations—			
	Pleistocene	Wisconsin glacial drift (Lake and stream deposits (0–300+))	0—270+	Clay, sand, gravel, and boulders, with lenses of stratified sand and gravel. (Lake and stream deposits: stratified clay, silt, sand and gravel.)	Supplies a few wells and springs in northeastern part of area. Water generally good. (Glacial lake and stream deposits: most productive deposits in area. Water generally good but locally iron-bearing. Nonglacial stream deposits yield small supplies in Cameron and Potter Counties.)
		—Unconformable on older formations—			
		Illinoian glacial drift	Thin	Thin veneer of reddish clayey till.	Unimportant as source of ground water.
		—Unconformable on older formations—			
		Jerseyan glacial drift	Very thin	Represented only by scattered erratic boulders.	Unimportant as source of ground water.
		—Unconformable on older formations—			
Carboniferous	Pennsylvanian	Conemaugh formation	0—100	Represented only by lowest member, Mahoning sandstone, which caps a few hills in southernmost Elk County.	Not utilized in this area.
		Allegheny formation	269—325	Variable sequence of sandstone, shale, limestone, clay, and coal. Complete section only in Elk County.	Sandstones productive locally in Elk County, unimportant elsewhere. Water poor near coal mines, and generally contains considerable iron and hydrogen sulphide.
		Pottsville formation	160—300	Olean conglomerate member at base overlain by Sharon shale and coal, Connoquenessing sandstone, Mercer shale and coal, and Homewood sandstone members.	Sandstones very productive in Elk and McKean Counties where below drainage level, yield small to moderate supplies elsewhere. Many waters contain iron.
		—Unconformity—			
	Mississippian	Mauch Chunk shale	0—100	Red and green shale, with some green and buff sandstone.	Not utilized in this area.
		WESTERN PART OF AREA: Knapp formation* / EASTERN PART OF AREA: Pocono formation	66—650	In McKean County, largely marine conglomerate, sandstone, and shale (Knapp). At east and south, nonmarine Pocono, mainly gray or white sandstone, with some conglomerate and shale.	Where they are below drainage level the Pocono, Knapp, and Oswayo formations are most productive consolidated rock formations in area. Some wells yield 300 to 600 gallons a minute. Waters generally soft, but many contain considerable iron.

* The Federal Geological Survey classifies the Cattaraugus, Oswayo, and Knapp formations as Upper Devonian or Mississippian.

General section of the geologic formations in north-central Pennsylvania—Continued

System	Series	Subdivisions	Thickness (feet)	Character of material	Ground-water conditions
Devonian	Upper Devonian	—Disconformity—			
		Oswayo formation*; Cattaraugus formation* (Catskill group of Willard)	500—2,000±	Mainly red shale, with some interbedded red and greenish-gray sandstone (Cattaraugus in west, Damascus, Honesdale, and Cherry Ridge of Willard in east), overlain by greenish-gray sandstone and sandy shale (Oswayo in west, Elk Mountain of Willard in east).	Catskill, Cattaraugus and Chemung generally yield adequate supplies for domestic use, and yield moderately large supplies to most industrial and public supply wells. Many Chemung and a few Catskill waters are brackish or salty. Some waters contain noticeable amounts of iron and hydrogen sulphide. Some Chemung waters contain natural gas.
		Chemung formation	1,760± to 2,100±	Interbedded greenish-gray and gray shales, sandy shales, and fine-grained sandstones.	
		Portage group	2,300—3,000	Gray to greenish-gray sandstone (Trimmers Rock of Willard), greenish-gray shale and sandstone (Brallier), soft brownish-gray or olive-green shale (Harrell) with black fissile shale (Burket member) at the base.	Yield small to moderately large supplies. Waters moderately hard to hard, some contain hydrogen sulphide; iron content usually low. Yields of more than 100 gallons a minute reported in several wells in Hamilton and Marcellus.
		Tully limestone	80-240	Limestone.	
	Middle Devonian	Hamilton formation	1,200—1,500	Olive-green shale and sandstone.	
		Marcellus shale		Fissile black shale with limestone concretions.	
		Onondaga formation		Limestone and shale.	Utilized by very few wells, one well reported to yield 75 gallons a minute.
	Lower Devonian	Oriskany group	174—178	Ridgeley sandstone at top, gray calcareous sandstone, 65-93 feet thick, underlain by Shriver formation, thin-bedded sandy shale, 81-113 feet thick. Both weather to buff color.	Utilized by very few wells. Ridgeley yields 400 gallons a minute to one well. Water probably soft.
		—Disconformity—			
		Helderberg limestone	225	New Scotland, Coeymans, and Keyser† limestone members. Ranges from dense limestone to impure shaly, sandy, or cherty limestone.	Yields small to moderately large supplies of hard to very hard water.

* The Federal Geological Survey classifies the Cattaraugus, Oswayo, and Knapp formations as Upper Devonian or Mississippian.

† The Keyser limestone member has been assigned to the Silurian system by Swartz, F. M., in Willard, Bradford, Devonian of Pennsylvania (in press).

General section of the geologic formations in north-central Pennsylvania—Continued

System	Series	Subdivisions	Thickness (feet)	Character of material	Ground-water conditions
Silurian		Cayuga group	1,000±	Probably divisible from top to bottom into: Tonoloway limestone; Wills Creek shale, buff and pale green calcareous shale and limestone; Bloomsburg redbeds, red shale and sandstone; and McKenzie formation, shale and/or limestone.	Limestone and calcareous shales yield small to moderately large supplies of hard to very hard water. Bloomsburg redbeds yield small supplies of good water.
		Clinton formation	800±	Green, gray, brown, and red shale and sandstone with thin beds of hematite iron ore.	Supplies a few hillside wells and springs with small supplies of soft water.
		Tuscarora quartzite	500±	Mainly light-gray or white quartzite with some red and green sandstone near the top locally.	Supply numerous small hillside springs and possibly a few domestic wells with small supplies of very soft water.
Ordovician	Upper Ordovician	Juniata formation	1,000±	Red shale and sandstone, with some gray sandstone.	
		Oswego sandstone	800±	Hard, thick-bedded, greenish-gray sandstone, with some conglomerate.	
		Reedsville shale	800±	Brown, gray, and greenish shale with some calcareous and sandy beds.	Unimportant in this area, no wells observed. In south-central Pennsylvania it generally yields small but dependable supplies of good water. Water may contain hydrogen sulphide locally.
	Middle and Lower Ordovician	Undifferentiated limestones and dolomites	1,000±	Gray to blue limestone and dolomite.	Unimportant in this area. Would probably yield adequate supplies of moderately hard water to wells that encounter solution channels. Give rise to two large tubular springs.

GEOLOGIC HISTORY AND GEOMORPHOLOGY

PRE-CAMBRIAN TIME

No rocks of pre-Cambrian age are exposed in the area, but pre-Cambrian gneisses, granites, and schists overlain by lavas are exposed in southeastern Pennsylvania, and form the ancient surface upon which the succeeding Paleozoic sediments were deposited. A considerable epoch of erosion intervened between the formation of the youngest pre-Cambrian rocks and the beginning of Paleozoic sedimentation.

CAMBRIAN PERIOD

Southeastern and south-central Pennsylvania and probably also north-central Pennsylvania were beneath sea level during the Cambrian period, and into this body of water were discharged first coarse sediments that formed strata of sandstone, conglomerate, and shale. The conditions of sedimentation changed several times allowing the deposition of several thick series of limestones and dolomites alternating with thinner beds of clastic materials.

Beds of Cambrian age do not crop out in the area described, but probably underlie the Ordovician rocks exposed in Lycoming County.

ORDOVICIAN PERIOD

Widespread submergence continued during the Ordovician period, allowing the deposition of a thick series of limestones and dolomites, some of which are exposed by the Nittany anticline in Nippenose and Mosquito Valleys, Lycoming County. Ordovician limestone is believed to underlie the entire area and has been reported in a deep well drilled at Erie, northwest of the area. Several temporary emergences of the land are recorded in the early Ordovician strata of south-central Pennsylvania.

The deposition of the succeeding Reedsville shale marked the beginning of a widespread change in land and sea conditions in the Appalachian region, and the shallow sea received dominantly clastic sediments until nearly the close of the Silurian period. After Reedsville time the fine sand of the Oswego sandstone and the red sands and muds of the succeeding Juniata formation were deposited. The absence of fossils in the Oswego, Juniata, and succeeding Tuscarora rocks together with the presence of red beds in the Juniata and locally in the Tuscarora suggests terrestrial deposits or perhaps shore deposits.

SILURIAN PERIOD

The Silurian period began with the widespread deposition of pure quartz sand, forming the hard Tuscarora quartzite of which Bald Eagle and White Deer Mountains are formed. In southeastern Pennsylvania the absence of the Juniata beneath the Tuscarora may indicate an emergence in that area preceding the Silurian.

The area was again submerged, and the sands and muds of the Clinton formation were deposited. The most distinguishing feature of the Clinton formation is the occurrence of beds of fossil and oolitic iron ore extending from New York to Alabama, which indicates a remarkable uniformity of conditions over a very large area.

Clinton time may have been followed in southern Lycoming County by an unrecorded interval during which the Lockport dolomite was deposited in the remainder of the area and in New York, although there is some evidence that the McKenzie formation may have been laid down here during part of this interval. During the next submergence the Cayuga group was deposited, comprising (where exposed southwest of Lycoming County) the McKenzie formation, the Bloomsburg redbeds, the Wills Creek shale, and the Tonoloway limestone.

DEVONIAN PERIOD

The Devonian period began with the deposition of the Helderberg limestone, followed by the deposition of the chert, siliceous limestone, and calcareous sandstone of the Oriskany group. In the succeeding Onondaga epoch shale and limestone were deposited.

After Onondaga time a thick series of shales, sandstones, and some limestones was deposited in shallow water during a long period of slow and constant subsidence of the sea floor, comprising the Marcellus, Hamilton, Tully, Portage, and Chemung units. The Catskill type of sedimentation, commonly regarded as the deposition of continental delta materials interfingering with marine deposits, began in eastern New York during Hamilton time, and the deposition of red shales and sandstones continued contemporaneously with the marine Portage and Chemung deposition and probably extended into early Mississippian time, rising in stratigraphic position progressively westward. Thus the Catskill diminishes in thickness from several thousand feet at the east to only a few hundred feet in western Pennsylvania. In northwestern Pennsylvania the dominantly red beds above the Chemung are known as the Cattaraugus formation. The Cattaraugus was succeeded by the deposition of greenish-gray sandy shales with interbedded shaly sandstone comprising the Oswayo formation.

CARBONIFEROUS PERIOD

Mississippian epoch.—Mississippian time began in the eastern part of the area with the deposition of the marine and nonmarine sands of the Pocono formation. In the western part the Knapp formation is considered by geologists who have worked in the area to be the equivalent of the Pocono. The Mississippian age of both these formations is, however, doubted by some geologists.

The deposition of the prevailingly gray Pocono and Knapp was succeeded by another extensive deposition of red beds, known as the Mauch Chunk shale, which is contemporaneous with marine limestones and shales in southwestern Pennsylvania and Ohio. Although the Mauch Chunk is several thousand feet thick at its type locality in northeastern Pennsylvania, its thickness diminishes to less than 100 feet in the northwestern part of this area, and in places it is absent. These facts indicate that most of the area west of the Allegheny Front was uplifted and the Mauch Chunk was largely eroded before the deposition of the overlying Pottsville.

Pennsylvanian time.—During Pottsville time about 1,000 feet of conglomerate and sandstone containing many coal beds was deposited in eastern Pennsylvania and about 10,000 feet was deposited in Alabama. While these thick sediments were being laid down elsewhere,

north-central and western Pennsylvania stood well above sea level and were subjected to extensive erosion, but near the end of Pottsville time the land submerged and the Olean conglomerate member, Sharon shale and coal members, Connoquenessing sandstone member, and Mercer shale and coal members were deposited. At many places in this area the Mauch Chunk was completely eroded away so that the Pottsville was deposited directly on the Pocono or Knapp.

The succeeding Allegheny epoch was accompanied by rapidly alternating conditions resulting in the repeated deposition of shale, sandstone, limestone, and coal. The Allegheny formation contains most of the coals mined commercially in this area. It is generally regarded that these coals were formed in fresh water marshes near sea level and generally extended over thousands of square miles. Plants of various types grew luxuriantly in these marshes, and their remains accumulated as extensive peat bogs. Alternate subsidence below and emergence above sea level were repeated many times so that numerous beds of coal with their underclays were accumulated with intervening beds of shale, sandstone, and limestone.

A marked change in the conditions of vegetation and sedimentation followed the close of Allegheny time, and a thick series of sandstones, shales, and locally thin limestones composing the Conemaugh formation was deposited. Brief recurrences of coal-forming conditions occurred throughout deposition, but the coals are generally too thin to be of widespread commercial value.

The Conemaugh epoch was succeeded in southwestern Pennsylvania by the deposition of the Monongahela formation, which was marked by another great period of coal formation and a series of events similar to those outlined for the Allegheny formation. The Monongahela epoch was succeeded by the deposition of the shales, sandstones, limestones, and thin coals of the Dunkard group (Permian). The Monongahela and Dunkard, if ever present, have been entirely removed by erosion from the area covered by this report.

TIME OF DEFORMATION ABOUT THE CLOSE OF THE PALEOZOIC ERA

The Dunkard epoch ended Paleozoic sedimentation in Pennsylvania, and an uplift of the sea bottom followed, accompanied by a period of strong lateral deformation known as the Appalachian revolution, by which the originally horizontal sediments were highly folded and faulted.

During the Appalachian uplift the flat-lying Paleozoic rocks from the southeastern border of the area to the Allegheny Front were subjected to extreme lateral compression, but the effect of this deformation gradually died out west of the Allegheny Front. As the compression increased the strata were more intensely folded, and the upfolds or anticlines rose higher and steeper and in some places south of the area were overturned toward the northwest. In some places the once horizontal beds now stand nearly vertical or are actually overturned. As some of the folds south of the area were overturned, they were broken and one part overrode another, sometimes for considerable distances. Southeast of the Allegheny Front the rocks have been folded into numerous high anticlines and deep synclines. Northwest of the Allegheny Front the rocks have been folded into low anti-

clines and synclines in some places but remain nearly horizontal in other places. Subsequent erosion has led to the development of a relief in close accordance with the occurrence of hard and soft rocks, so that the general structure of the area south of the Allegheny Front is easily recognized in the present-day topography.

The structure of the Plateaus region of northern Pennsylvania including the area described in this report, has recently been studied by Cathcart[3] as a result of widespread interest in the discovery of gas in the Oriskany on anticlinal structures. A part of his structure map, to which have been added several folds in southern Lycoming County, is shown in plate 4.

In describing the structure of the Plateaus region Cathcart says (page 7): "Practically all the area shown [in plate 4] lies on the eastern limb of the Appalachian geosyncline. The system of folds is arcuate; in the western part of the area structures trend about N.55°E., in the eastern part about N.75°E. The regional plunge of all structures is southwestward. In general the amplitude of folds and the steepness of their limbs diminishes with distance from the Allegheny Front. With few exceptions folds are asymmetric, with slightly steeper south than north limbs."

According to Cathcart the maximum amplitude of folding between adjacent structural axes ranges from 1,000 to 3,000 feet, the latter being the amplitude between the Ramseyville syncline and the Tombs Run anticline.

To quote further from Cathcart: "Faulting has long been recognized as an important element of structure in highly folded Appalachian Valley [Valley and Ridge] province just east [or south] of the Allegheny Front but in general the strongly contrasted gentle folds of the Appalachian plateaus have not been thought of as being faulted structures. More careful examination of the anticlines of northern Pennsylvania and recent deeper drilling in Potter and Tioga Counties has shown very conclusively that, in that region at least, faulting * * * is of more general occurrence than supposed * * *."

Southern Lycoming County is the only part of the area affected by the strong folding which characterizes the Valley and Ridge province. The structure in this part of the area is very clearly shown by the topographic maps of the Williamsport and Milton quadrangles. Bald Eagle Mountain and North White Deer Ridge, which merge together at the east, form the limbs of the Nittany arch—one of the major structural features of the State. This fold extends as far as Bedford County, a distance of 150 miles, and in Blair and Huntingdon Counties it reaches a maximum width of 35 miles.

MESOZOIC AND TERTIARY TIMES

The Appalachian uplift at the close of the Paleozoic terminated sedimentation in the area, and the history thereafter was one of continued erosion, given renewed vigor by subsequent uplifts. After the first

[3] Cathcart, S. H., Geologic structure in the Plateaus region of northern Pennsylvania and its relation to the occurrence of gas in the Oriskany sand: Pennsylvania Topog. and Geol. Survey, Bull. 108, 24 pp., 1 pl., 2 figs., Mar., 1934.

uplift the land remained stationary with respect to sea level for a long time, so that hard and soft rocks alike were eroded to form a nearly featureless surface sloping gently toward the sea, known to geologists as a peneplain. Sometimes during the later part of the Mesozoic era, the land was again uplifted, and vigorous erosion was resumed. This second period of erosion was not long enough to reduce the entire area again to a nearly flat surface, but was sufficient to carve out the deep valleys in the softer rocks, leaving remnants of the preexisting peneplain strikingly preserved in the flat, even crests of the high sandstone ridges in the Valley and Ridge province, the bold escarpment known as the Allegheny Front (plate 3A), and the higher ridges in the Plateaus province.

A still later uplift (commonly referred to the early Tertiary) caused the streams to begin actively eroding their channels below the level of the valleys, leaving broad rolling areas above stream level. This incomplete peneplain has been called the Harrisburg peneplain after the city of Harrisburg which is built on a remnant of this old surface. Like the old Mesozoic surface, the Harrisburg surface is not level, but slopes downward on all sides from the area of maximum uplift in Potter and McKean Counties.

There is evidence that important drainage changes took place during the Tertiary in New York, and northern Pennsylvania. Fairchild[4] presents convincing evidence that at one time, presumably early Tertiary, the Upper Delaware River and Upper Susquehanna River joined just north of the Pennsylvania State line, flowed south through Susquehanna County, Pennsylvania, along the valley of the now north-flowing Canawacta Creek, through what is now a "wind gap" at Rosskelly corners, and thence down the valley now occupied by Tunkhannock Creek to the present channel of the Susquehanna in Wyoming County. Similarly, he shows that the Chenango once flowed south from Binghampton into Susquehanna County, down the now north-flowing Salt Lick Creek, through a low pass, and thence down the valley of Martins Creek to join the ancient Susquehanna at Nicholson. Several other streams to the west in Bradford County also appear to have had different courses at this stage in their history, notably Wappasening Creek, which apparently once flowed south instead of north, through a gap 1½ miles southeast of Windham Center, and thence down Wysox Creek. Fairchild believes that during the late Tertiary the streams draining most of the northern tier of counties described in this report and the adjacent counties of Warren and Susquehanna flowed north to what he calls the ancient "Erigan and Ontarian Rivers," which flowed west and joined the Mississippi. According to this hypothesis the Susquehanna River (without the present upper Delaware) flowed as it does today as far south as Waverly, New York, whence it flowed northward past Elmira and along the valley now occupied by Lake Seneca to the ancient "Ontarian River." In Bradford County, a small stream flowed north along the valley in which the Susquehanna River now flows south. The Genesee

[4] Fairchild, H. L., The Susquehanna River in New York and evolution of western New York drainage: New York State Museum Bull., No. 256, pp. 25-38, 1925.

River apparently flowed north as it does today except for changes near its mouth.

That part of the Allegheny River draining southwestern New York and the northwestern part of the area covered by this report apparently flowed northward toward Lake Erie in the late Tertiary, but there has been some difference of opinion as to the exact course followed. This was first described by Carll,[5] who believed that the water reached Lake Erie by way of Cassadaga Creek. Leverett[6] and later Fairchild[7] believed that the drainage entered Lake Erie by way of Cattaraugus Creek, but Leverett has recently published a map[8] showing the outlet as originally described by Carll.

PLEISTOCENE EPOCH

During the Pleistocene epoch the northeastern part of the area is believed to have been covered three times by great ice sheets coming from the north, which, according to Leverett,[9] reached as far south and west as the glacial boundaries shown on plate 1.

As the ice advanced, the soil and decomposed rock were scraped off and shoved along by the great weight and lateral force of the glacier. Masses of bedrock were plucked out by the ice and, held firmly, formed tools with which the glacier scoured the bedrock. Many grooves and striae produced in this manner are still preserved on smooth rock surfaces and show that the general direction of ice movement was toward the southwest but locally the direction was governed somewhat by the preglacial topography and ranged from nearly south to due west.

During the retreat of the glaciers, the rock materials that had been accumulated during the advance were left scattered over the surface, either as a veneer of drift covering the bedrock, in piles or mounds known as moraines, one of which is shown in plate 5A, or as lake and stream deposits.

In revising the original mapping of the terminal moraine[10] which marks the southernmost advance of the glaciers, Leverett[11] reached the conclusion that "A part of the drift now seems to correspond in age to the Illinoian or third drift of the North American series, while a part seems old enough to correlate with either the first or second drift of this series. The older drift as exposed in New Jersey has been termed the Jerseyan drift, and the same drift appears to be present in eastern Pennsylvania."

During the advance and retreat of the several continental glaciers that invaded the area, the swollen south-flowing streams that issued from the melting ice-sheets transported an immense quantity of material. Whenever the quantity of material exceeded the transporting power of the streams, the material was dropped, partly filling the

[5] Carll, J. F., Geology of the oil regions of Warren, Venango, Clarion, and Butler Counties: Pennsylvania Geol. Survey, 2d ser., Rept. I-3, p. 354, 1880.

[6] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins: U. S. Geol. Survey, Mon. 41, pp. 89, 129-130, 1902.

[7] op. cit., pl. 5.

[8] Leverett, Frank, Glacial deposits outside the Wisconsin Terminal Moraine in Pennsylvania: Pennsylvania Geol. Survey, 4th ser., p. 93, 1934.

[9] Idem., pl. 1.

[10] Lewis, H. C., Report on the terminal moraine in Pennsylvania and western New York: Pennsylvania Second Geol. Survey, Rept. Z, 299 pp., 1884.

[11] op. cit., pp. 24.

PLATE 5

A. Glacial moraine along State Highway 87, 1½ miles northwest of Colley, Sullivan County.

B. Hummocky drift bordering outwash-filled valley of Lycoming Creek. Looking downstream from a point near Fields Station, Lycoming County.

C. Pine Creek Canyon, cut by overflow from Glacial Lake Cowanesque. Looking downstream from lookout point in Harrison State Park, Tioga County.

valleys, as shown in plate 5B. In many places streams were diverted from their preglacial courses by damming or complete filling of stream valleys, and the numerous small lakes, such as Eaglesmere Lake in Sullivan County, originated by the damming of valleys by glacial drift. There is evidence[12] that the west Branch of the Susquehanna River was dammed by a lobe of the Illinoian glacier in the vicinity of Muncy, forming a large lake in the Susquehanna and Bald Eagle Valleys of Lycoming and Clinton Counties, now filled with lake and stream deposits and bordered by alluvial fans (see p. 132, and plate 2).

The advent of the glaciers had a profound effect on the north flowing streams that existed in New York and northern Pennsylvania in preglacial times, resulting in radical drainage changes. Fairchild[13] has shown that the advancing glaciers effectively dammed these north flowing streams, creating a large chain of lakes in western New York and extending into the area described in this report. The northern outlets of these lakes being effectively blocked, the waters rose until they spilled over into some south-flowing drainage system, and then began vigorously cutting down their new-found outlets, pouring a tremendous flood down the southward draining streams. After the retreat of the last or Wisconsin glacier, the damming and filling of stream channels at the north and the channel cutting at the south were sufficient to allow the permanent reversal in flow of many of the major streams, so that today both the Susquehanna and Allegheny Rivers retain their southward flow, the former having found a new channel across southeastern Bradford County (see plate 6). Many of the tributary streams were reversed and captured by south-flowing streams, a notable example being found in southwestern Tioga County. There an arm of a glacial lake formed by the damming of the Cowanesque and Tioga Rivers found a new outlet through a tributary of Pine Creek, near the village of Ansonia, and the overflow continued long enough to cut the deep canyon of Pine Creek south of Ansonia (plate 5C), called by some the "Grand Canyon of Pennsylvania." After several successive glacial lakes had been drained and the ice had retreated for the last time, Pine Creek continued to drain a part of the old lake basin, including Pine Creek northwest of Ansonia, and Marsh Creek, which heads near Stokesdale Junction in a wide flat "through valley" and flows south in the opposite direction to that of the preglacial course. Other examples of drainage reversals will be cited in the county descriptions.

Glacial spillways noted by previous investigators[14] and those observed by the writer are shown on plate 2 and noted in the county descriptions. More features of this type will probably be found after the topographic mapping of north-central Pennsylvania has been completed.

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[12] Leverett, Frank, op. cit., pp. 34-41, 56-58.

[13] op. cit., pp. 39-92.

[14] Fairchild, H. L., Glacial Genesee lakes: Geol. Soc. America Bull., vol. 7, pp. 433-436, pl. 19, 1896.

Fuller, M. L., and Alden, W. C., Description of the Gaines quadrangle: U. S. Geol. Survey, Geol. Atlas, Gaines fol. (no. 92), surficial geol. map, 1903.

——————, Description of the Elkland and Tioga quadrangle: U. S. Geol. Survey, G. Atlas, Elkland-Tioga fol. (no. 93), surficial geol. map, 1903.

Ashley, G. H., States "Thru Valleys" formed as nature solved drainage problem: Pennsylvania Dept. of Internal Affairs, Monthly Bull., vol. 4, no. 4, pp. 25-28, September, 1937.

PLATE 6

A. Looking upstream along the Susquehanna River now flowing south over buried valley 3 miles north of Towanda, Bradford County. River flowed north in pre-glacial times. (Infra-red photo.)

B. Looking south (downstream) along new post-glacial course of the Susquehanna River southeast of Towanda. (Infra-red photo.)

The glacial lakes in north-central Pennsylvania remained long enough to become partly filled with accumulations of gravel, sand, silt and clay, and tributary streams built up deltas and alluvial fans where they joined such bodies of water, which now remain as terraces (plate 7). These lakes and stream deposits, and the glacial outwash

PLATE 7

Terrace along margin of buried valley formerly occupied by Lake Cowanesque. Looking west from the middle of Crooked Valley just south of Middlebury Center, Tioga County.

along other streams, are the most productive water-bearing materials in the area. For this reason, an attempt has been made to show the extent and known depth of such deposits in plate 2. This map is not based on detailed field mapping, but was compiled from field notes and numerous well records with the aid of the excellent topographic maps covering part of the area, and where solid boundaries are shown it is believed to be essentially correct. Where data are lacking, especially in areas that have not been mapped topographically, dashed boundaries or question marks are used. Details and questionable areas are discussed under Pleistocene series and in the county descriptions.

Cameron and Elk Counties, and southern McKean and Potter Counties were not glaciated, and a high divide separates the south-flowing streams in these counties from those draining glaciated areas or those dammed by glaciers. The Clarion River and its tributaries in Elk County and southern McKean County flow in narrow bedrock channels that contain little or no alluvium. However, alluvial deposits are found at numerous places along Sinnemahoning Creek and its tributaries which drain Cameron County and southern Potter County. They are 10 to 30 feet thick in parts of southern Potter County, and are about 50 feet thick locally in Cameron County between Emporium and Sterling Run, and perhaps below Sterling Run. Similar deposits 40 to 65 feet feet thick have been tapped by wells between Hyner and Renovo, in Clinton County.[15] Farther upstream at Westport, Clinton County, a well penetrated 70 feet of sand and gravel.

[15] Lohman, Stanley W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 5, p. 122. 1938.

In Clinton County, and to a certain extent in Cameron County, these deposits occur mainly above present stream level, generally only in the wider parts of the valleys, and are especially prominent in Clinton County at points where small streams enter the main valley. Young Womans Creek in particular has dumped considerable material near its mouth. Between Hyner and Renovo the material remains in terraces bordering the river, which has cut through to bedrock in most places. In the narrower parts of the valley, all unconsolidated material, if ever present, appears to have been removed, and the river flows over a bedrock channel. The only unconsolidated material noted in Elk County is that penetrated by well 138 in Horton Township, and appears to be only of local significance, and may well be of recent origin. No attempt has been made to show the areal extent of these deposits in plate 2, because there are no topographic maps for this part of the area, because there are very few wells for which accurate information is available, and because the deposits are discontinuous as indicated above.

What is the source of this material? The absence of topographic maps for this area is a severe handicap to the solution of this problem, but the following observations appear to indicate a possible mode of origin for these deposits.

An old report[16] gives an altitude of 1,881 feet for the Pennsylvania Railroad at Keating Summit, Potter County. Here the railroad crosses the divide in a narrow pass or col, through which water may have spilled from the glacial lake occupying northern McKean County. However, from a brief study of the maximum altitude of lake deposits in small arms of this lake, it does not appear likely that the glacial lake could have remained long at an altitude sufficient to allow water to escape through this pass, nor does the pass appear to have suffered any appreciable stream erosion. The only other railroad traversing southern Potter County, the Baltimore and Ohio, ascends and descends the high divide by a series of steep switch-backs, and crosses the divide at Cherry Spring Station, in West Branch Township. The old Coudersport Pike crosses the railroad at the highest point over a viaduct on which is a United States Geological Survey benchmark stamped 2,234.6 feet. It is extremely unlikely, therefore, that any glacial water crossed the divide at this point, and it seems reasonable to suppose that if any lower pass exists the railroad would have used it instead of the steep switch-back approach to the pass at Cherry Springs. Some of the deposits in southern Clinton County were laid down in the slack water of the Illinoian lake in the Bald Eagle-Susquehanna Valley, but this would not account for the deposits farther upstream in northern Clinton County and in Cameron and Potter Counties. In the absence of conclusive evidence that glacial lake waters could have spilled over into this drainage system for any appreciable time, the writer prefers to postulate that the deposition of these gravels resulted from changes in the gradients of the streams during the Pleistocene, for reasons given below.

[16] Sherwood, Andrew, The geology of Potter County: Pennsylvania Second Geol. Survey, rept. GGG, p. 3, 1880.

The maximum uplift during the early Tertiary is believed to have taken place in Potter and McKean Counties,[17] in the headwater area of the streams under consideration. This high point was also avoided by all of the Pleistocene glaciers, whose southern borders curved around this point. During the period of maximum uplift preceding glaciation, the streams radiating from this high point acquired increased cutting power and incised themselves deeply into the Plateau.

During the Pleistocene it is believed that the great glaciers attained thicknesses of possibly several thousand feet at the gathering grounds in Labrador, but obviously they were thinner near their borders. On the basis of good evidence Fairchild[18] has shown that the great weight of this ice depressed the land by as much as 1,000 feet in Labrador, and by correspondingly smaller amounts in the areas concentric around this point. After the enormous weight was removed by the melting of the ice, the land rose gradually to about its former level, and perhaps is still slowly rising. On a map of New York and Pennsylvania, Fairchild[19] shows lines of equal Pleistocene uplift (isobases). The zero line indicating no uplift passes in a west-northwest direction through southern Elk County, and just southwest of Cameron and Clinton Counties. On the basis of this map Cameron and Clinton Counties appear to have been depressed and subsequently elevated by amounts of 20 to 40 feet, even though entirely southwest of the glacial borders. The amount was possibly 50 feet in southern Potter County and much less in Elk County.

When this area subsided, the stream gradients were correspondingly reduced so that the streams ceased to erode their channels, and instead began to deposit the gravels and sands under discussion. When the glaciers retreated for the last time, the land rose to approximately its former altitude, and with the reestablishment of the old stream gradients, the streams once again began to erode their channels and remove the deposited material. Since the last Pleistocene uplift sufficient time has elapsed for these streams to carry away most of the material, only remnants of which remain as terraces. The apparent absence of such deposits in Elk County seems to indicate that this county was not appreciably affected by Pleistocene subsidence or uplift. On the basis of the evidence presented above, the writer is of the opinion that Fairchild placed the zero isobase in his earlier map[20] a little too far south and in his later map[21] a little too far north, and that the line should just touch the southwestern borders of Cameron and Clinton Counties, and traverse northeastern Elk County.

RECENT EPOCH

The events after the close of the Pleistocene epoch have not materially changed the features of the area. Some additional drainage adjustments probably took place, and some of the streams have deep-

[17] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Geol. Soc. America Bull., vol. 14, pp. 277-296, 1903.
[18] Fairchild, H. L., Post-Glacial uplift of northeastern America: Geol. Soc. America, Bull., vol. 29, no. 2, p. 202, 1918.
[19] Fairchild, H. L., Pleistocene uplift of New York and adjacent territory: Geol. Soc. America, Bull., vol. 27, no. 26, plate 10, 1916.
[20] op. cit., plate 10.
[21] Fairchild, H. L., Post-Glacial uplift of northeastern America: Geol. Soc. America Bull., vol. 29, no. 2, p. 202, 1918.

ened their channels somewhat, particularly where they flow over easily eroded material filling the buried valleys. Other streams have built up slight flood plains in places where conditions became favorable for deposition.

GROUND WATER

SOURCE

Ground water, or underground water, is the water that issues from springs or can be pumped from wells. In north-central Pennsylvania ground water is derived almost entirely from precipitation in the form of rain or snow. Part of the water that falls as rain or snow is carried away to the ocean by the streams; part of it percolates downward into the rocks until it reaches the water table where it joins the body of ground water known as the zone of saturation; and part of it may evaporate or be absorbed and transpired by the vegetation and thus returned directly to the atmosphere.

The ground water percolates slowly through the rocks in directions determined by the topography and geologic structure, until eventually it is discharged through springs or wells; through seeps directly into the streams, or by evaporation and transpiration in lowlands bordering the streams. In some parts of the United States, the water obtained from wells has traveled many miles from the area of intake, but in north-central Pennsylvania the water obtained from shallow wells and springs is generally derived from precipitation in the immediate vicinity, and the water obtained from the deeper wells is derived from precipitation in the general vicinity—usually within the same or adjacent county.

In addition to water derived from precipitation (meteoric water) some of the rocks still contain some sea water that was entrapped in them at the time of their deposition (connate water). Saline water of this type is encountered in a few deep wells in parts of the Plateaus province.

Many of the residents of this area fallaciously attribute the source of the water in their springs or wells to far distant lakes or rivers. Other residents of the area believe that the ground water comes from nearby streams. This is partly true in some of the valleys in Lycoming County underlain by limestone where numerous small streams enter the ground through sink holes, but in the remainder of the area the streams generally do not lose water into the ground, except when flooded, and almost invariably receive water from the ground:

Some of the residents of the area may not believe that the amount of water falling as rain or snow is sufficient to supply the large underground reservoirs. However, one inch of water falling on one square mile amounts to 17,378,720 gallons, and the average annual precipitation in the area is about 39 inches, or approximately 678,000,000 gallons to the square mile. Part of this water reaches the underground reservoirs, as described above. The relation between the water level in wells and the precipitation is described under Fluctuations.

OCCURRENCE[22]

STORAGE AND MOVEMENT

The rocks forming the outer crust of the earth are generally not entirely solid, but contain numerous openings, called voids or interstices, which may contain either liquid or gas, such as water, oil, natural gas, or air. There are many kinds of rocks and they differ in the number, size, shape, and arrangement of their interstices and hence in the amount of water they are able to hold. The occurrence of ground water in any region is therefore determined by the geology.

The voids or interstices in rocks range in size from microscopic openings to the large caverns found in limestone regions, and may be classified according to their origin into primary and secondary interstices, according to whether the interstices were formed contemporaneously with the formation of the rock or were made by processes that affected the rock after it was formed. In this area the water-bearing rocks are all of sedimentary origin, and the openings that contain water are: (1) the pore spaces between the grains of the rocks; (2) the joints, crevices, and open bedding planes which have resulted from fracturing of the rocks; and (3) channels or caverns in limestone and dolomite which have resulted from the solution and corrasion of the rocks by water moving along the joints or bedding planes. The first two kinds of openings mentioned are the most important conduits of ground water in north-central Pennsylvania.

The amount of water that can be stored in any rock depends on the porosity of the rock, commonly expressed as the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when all of its interstices are filled with water. Several types of rock interstices and the relation of rock texture to porosity are shown in figure 3.

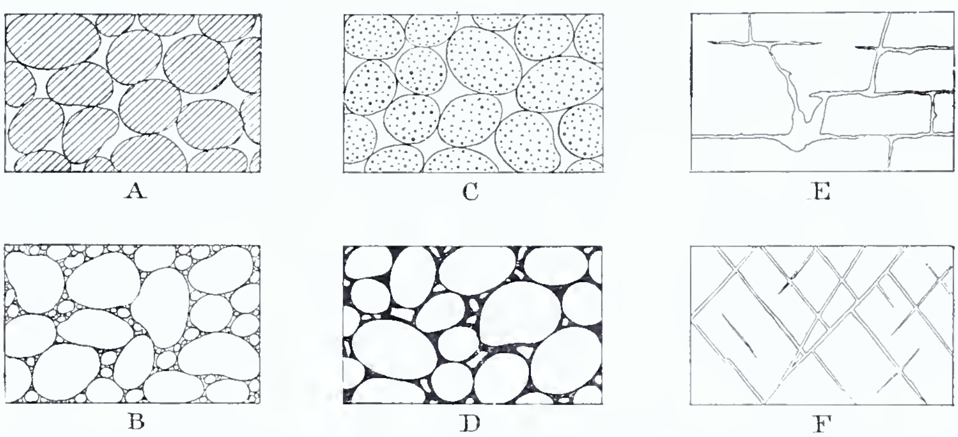


Fig. 3. Diagram showing several types of rock interstices and the relation of rock texture to porosity: A, well-sorted sedimentary deposits having a high porosity; B, poorly sorted sedimentary deposit having low porosity; C, well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; D, well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; E, rock rendered porous by solution; F, rock rendered porous by fracturing. (After O. E. Meinzer.)

[22] For a detailed treatment of the occurrence of ground water, see Meinzer, O. E., The occurrence of ground water in the United States with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, 321 pp., 110 figs., 31 pls., 1923.

Porosity alone determines only how much water a given rock can hold, not how much it may yield to wells. The permeability of a rock may be defined as its capacity for transmitting water under the force of gravity, and is measured by the rate at which it will transmit water through a given cross section under a given difference of pressure per unit of distance. A bed of silt or clay may have as high a porosity as a bed of coarse sand, but because of the small size of its interstices it may require the application of great pressure to transmit water, and, hence, under the incompetent force of gravity, it may be entirely impermeable. Moreover, not all of the water in a saturated rock is available to wells, because part of the water is held against the force of gravity by molecular attraction. In a fine-grained rock the molecular attraction is very great and only a small part of the water can be drained out by the force of gravity, whereas in a coarse sand or gravel having the same porosity, only a small part is retained by molecular attraction and the remainder becomes available to wells.

WATER TABLE

The permeable rocks that lie below a certain level in north-central Pennsylvania and elsewhere are generally saturated with water. These saturated rocks are said to be in the zone of saturation, and the upper surface of the zone of saturation is called the water table. The relation of the zone of saturation to the zone of aeration is shown in figure 4. The water that falls on the soil is slowly drawn down by gravity through the zone of aeration to the zone of saturation, except that which is retained by molecular attraction. In fine-grained material the earth is always moist several feet above the water table due to capillarity, and this moist belt is called the capillary fringe. The water retained in the capillary fringe is not available to wells, which must be sunk to the water table before water enters them.

Perched water.—Where permeable rock is homogeneous down to a considerable depth there is only one zone of saturation, but in some localities the water may be hindered in its downward course by a relatively impermeable bed and form an upper zone of saturation known as a perched water body. The water table is absent in places where impermeable material immediately overlies the zone of saturation. Bodies of perched water doubtless occur locally in some parts of north-central Pennsylvania, particularly in the thick blanket of soil and residual clay that overlies the rock in the limestone valleys of Lycoming County.

Relation to topography.—In north-central Pennsylvania the water table is an undulating surface that generally stands higher beneath upland areas than beneath the adjacent valley areas, and slopes gradually down to the level of the streams. In the areas between the streams the supply of ground water is replenished from the rain and snow, and hence the water table is built up above the level of the streams. As the ground water moves in the direction of the slope of the water table, its movement is toward the discharge areas along the streams. Thus, except at flood stages, the streams are commonly gaining water from the zone of saturation. A depression in the land sur-

face that intersects the water table may produce springs known as depression springs. The types of springs common in the area are discussed under Springs.

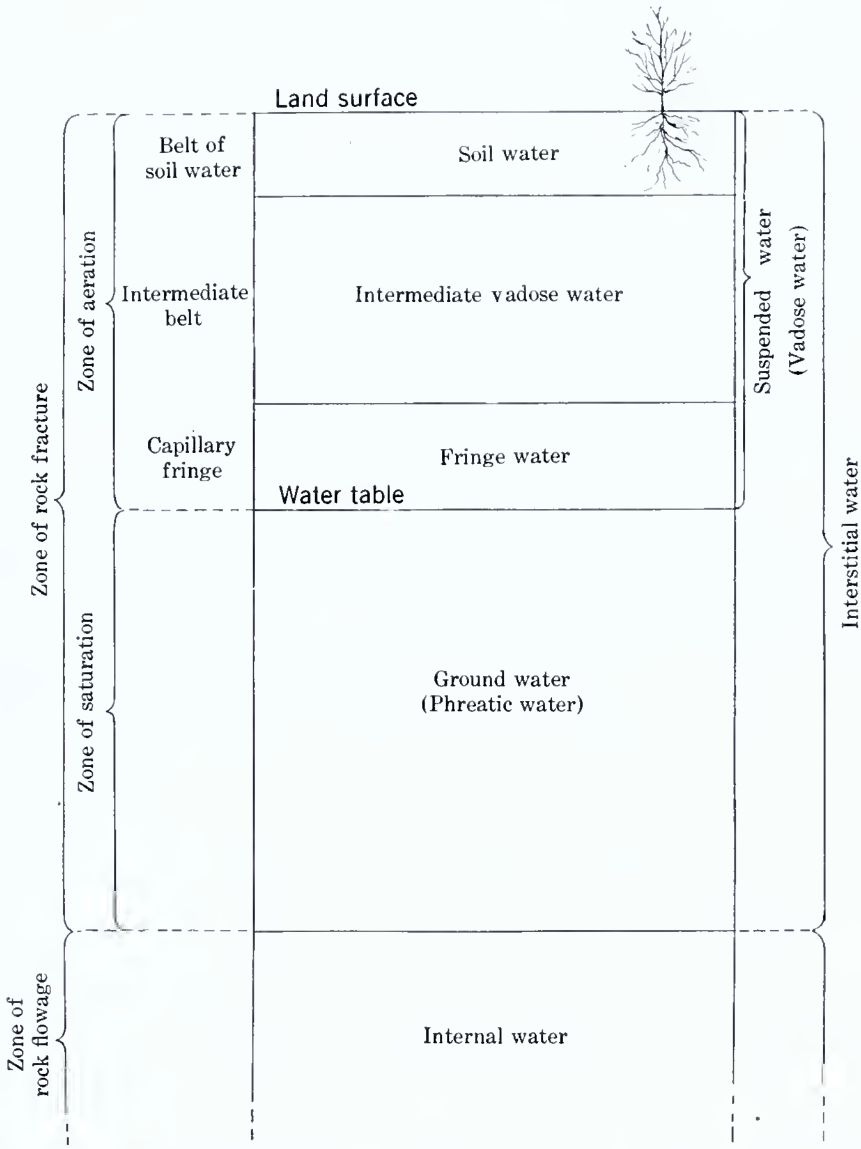


Fig. 4. Diagram showing divisions of subsurface water. (After O. E. Meinzer.)

Fluctuations.—There is a relation between the amount of water falling as rain or snow and the level at which the water stands in wells, but this relation is complicated by several factors. Other things being equal, the greater the precipitation for a given period the greater the rise in the water level; however, after a prolonged dry spell, the water contained in the soil becomes depleted, and when rain occurs, it must first replenish the soil moisture before any of the water can percolate down to the water table. The temperature also has an influence, for rain that falls on frozen ground is hindered appreciably from reaching the water table, and part of the water that falls during the hot sum-

mer months is evaporated directly into the air. With the coming of spring the vegetation begins to make heavy demands on the soil moisture and in some places where the tree roots extend down to the water table, the trees draw water directly from the zone of saturation. Thus, although the rainfall is greater during the summer, the water table generally declines due to the heavy consumption of water by vegetation. When the first killing frost occurs in the fall, transpiration of water ceases, and even though there may be no appreciable precipitation, the water level in wells on lowlands may rise somewhat and small springs may increase in flow. During the winter, at times when the ground is not frozen, the precipitation may percolate downward with little loss from evaporation and transpiration, and when the soil moisture has been replenished, a moderate amount of precipitation may cause an appreciable rise in the water table. The fluctuations of the water table are also dependent upon other factors, including the type of water-bearing material, topography, and depth to water. There is also a relation between the height of the water table and the low flow of the streams, which is largely ground water.

In the fall of 1931 a project was begun for obtaining systematic weekly records of ground-water levels in Pennsylvania, in cooperation between the Geological Survey, United States Department of the Interior, and the Pennsylvania Topographic and Geologic Survey.[23] The complete records for all wells that were being observed at the close of 1936 and 1937, including 6 observation wells in the area covered by the present report, together with the average weekly water levels for all observation wells in Pennsylvania, have recently been published.[24] All future well records are to be published in similar annual reports each year.

The location, period of record, and publication numbers for all observation wells located in this area are listed in the following table.

Observation wells in north-central Pennsylvania

County	Well number in this report	Well number in Water Supply Papers 817 and 840	Record begun	Remarks
Bradford	52	82	Nov., 1931	See fig. 5
Do	70	81	Sept., 1931	Do
McKean	316	108	Sept., 1935	See fig. 6
Potter	417	107	Aug., 1935	See fig. 6 and pl. 8A
Sullivan	425	105	Aug., 1935	Do
Tioga	495	106	Aug., 1935	Do

[23] Water levels and artesian pressure in observation wells in the United States in 1935: U. S. Geol. Survey Water-Supply Paper 777, pp. 161-169, 1936.

[24] Water levels and artesian pressure in observation wells in the United States in 1936: U. S. Geol. Survey Water-Supply Paper 817, pp. 260-301, 1937.

Water levels and artesian pressure in observation wells in the United States in 1937: U. S. Geol. Survey Water-Supply Paper 840, pp. 347-364, 1938.

None of these wells is used as a source of water. Number 316 is a drilled well, the rest are dug wells. As shown in the tables of well records, wells 52 and 316 are more than 50 feet deep, but the others range in depth from about 5½ to 28 feet. Well 52 is equipped with a direct-reading float gage, but in the others the water level is measured by lowering into the well a steel tape with a weight attached, as illustrated in plate 8A.

The weekly fluctuations of the water table in 4 observation wells in Bradford County, and the monthly precipitation at Towanda are shown in figure 5, for the period November, 1931, to December, 1937, inclusive. Figure 6 is a similar graph for 4 observation wells in other counties of the area, with the monthly precipitation at Galeton, a central point for the 4 wells, for the period August, 1935, to December, 1937, inclusive.

In well 70, figure 5, the maximum height to which the water may rise is limited by the land surface. The water level in well 417, figure 6, rises nearly to the surface in wet seasons. In the other wells, in which the water levels stand farther beneath the surface, the maximum height to which the water may rise is not so limited and, as will be shown, depends upon the amount of recharge received from precipitation. On the contrary, in well 316, figure 6, the minimum water level appears to be limited at a point about 36½ feet beneath the land surface, and the water apparently rises above this point only in response to exceptionally heavy recharge. Well 70, figure 5, and well 425, figure 6, do not extend far below the water table and hence go dry during certain periods of the summer. Well 425 was dry during all periods represented by gaps in the record, but well 70 was reported dry only from Sept. 24 to Oct. 8, 1932, the remaining gaps representing periods for which no measurements were made. For the other wells, gaps in the graphs represent periods during which no measurements were made. The topography in the vicinity of well 495, figure 6, suggests that this well may not reach the true water table and hence may tap a body of perched water held up by some clay layer in the terrace deposits which underlie the immediate vicinity. Hence the water level in this well, which shows a somewhat larger annual fluctuation than that of most of the wells, may indicate only the height of water in a small temporary storage basin, from which the water may percolate downward or laterally toward the zone of saturation.

The reader will probably wonder at the extremely large annual fluctuation in water level shown by well 52, figure 5. The true explanation for this is not known, as the well, which is 64 feet deep, was dug by hand many years ago, and no record has been kept of the strata penetrated. However, by making several assumptions, it is possible to arrive at a reasonable explanation for this peculiar behavior. The well is located on a steep hillside, on the edge of the Susquehanna Valley, and although all of Bradford County has been glaciated, the drift mantle in the vicinity of the well is believed to be rather thin, so that it may be assumed that most of the well is in shale of the Chemung formation. In contrast to most drilled wells which are cased to firm bedrock, this dug well is curbed for its entire depth with

PLATE 8

A. Observation well at Conrad, Potter County. Depth to water level being measured with steel tape.

B. Open joints in massive sandstone suitable as conduits of ground water. Greenish-gray sandstone (Salamanca member) and underlying red and greenish-gray shale of the Cattaraugus formation exposed in quarry northeast of Lewis Run, McKean County.

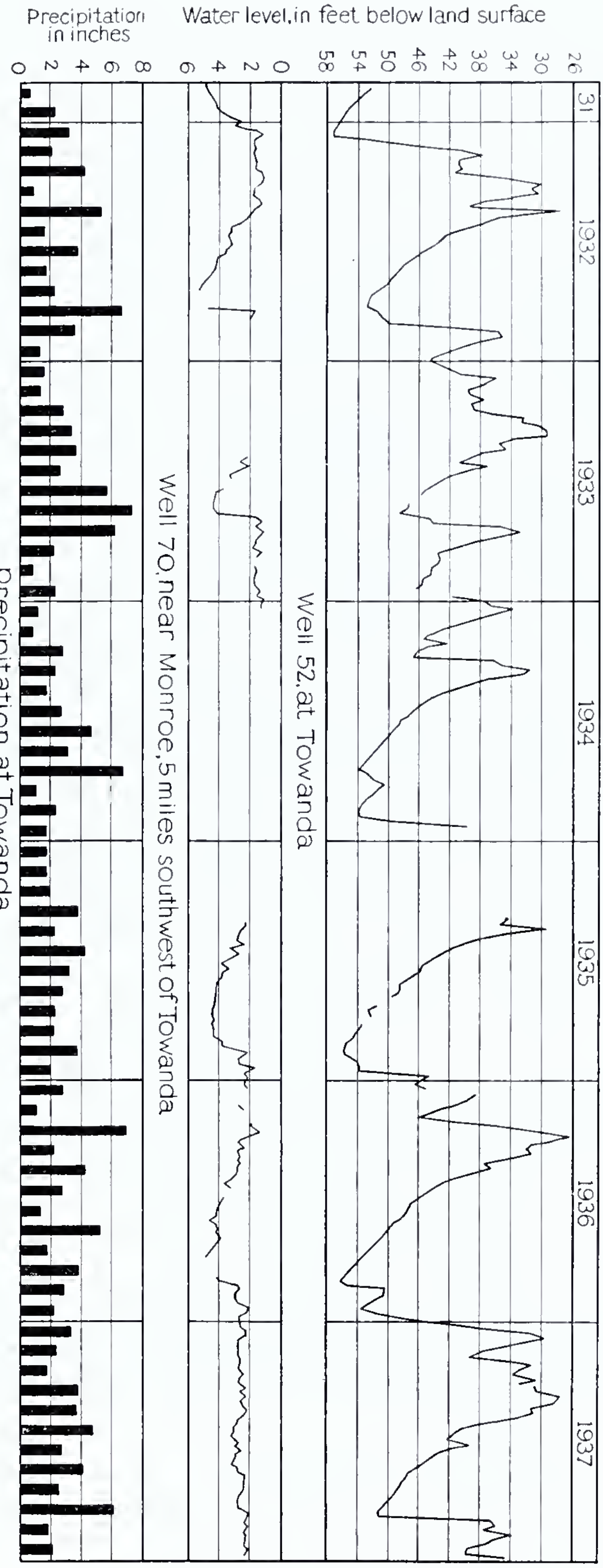


Fig. 5. Graphs showing the weekly fluctuations of the water levels in 2 observation wells in Bradford County, Pennsylvania, and the monthly precipitation at Towanda. Precipitation data from U. S. Weather Bureau.

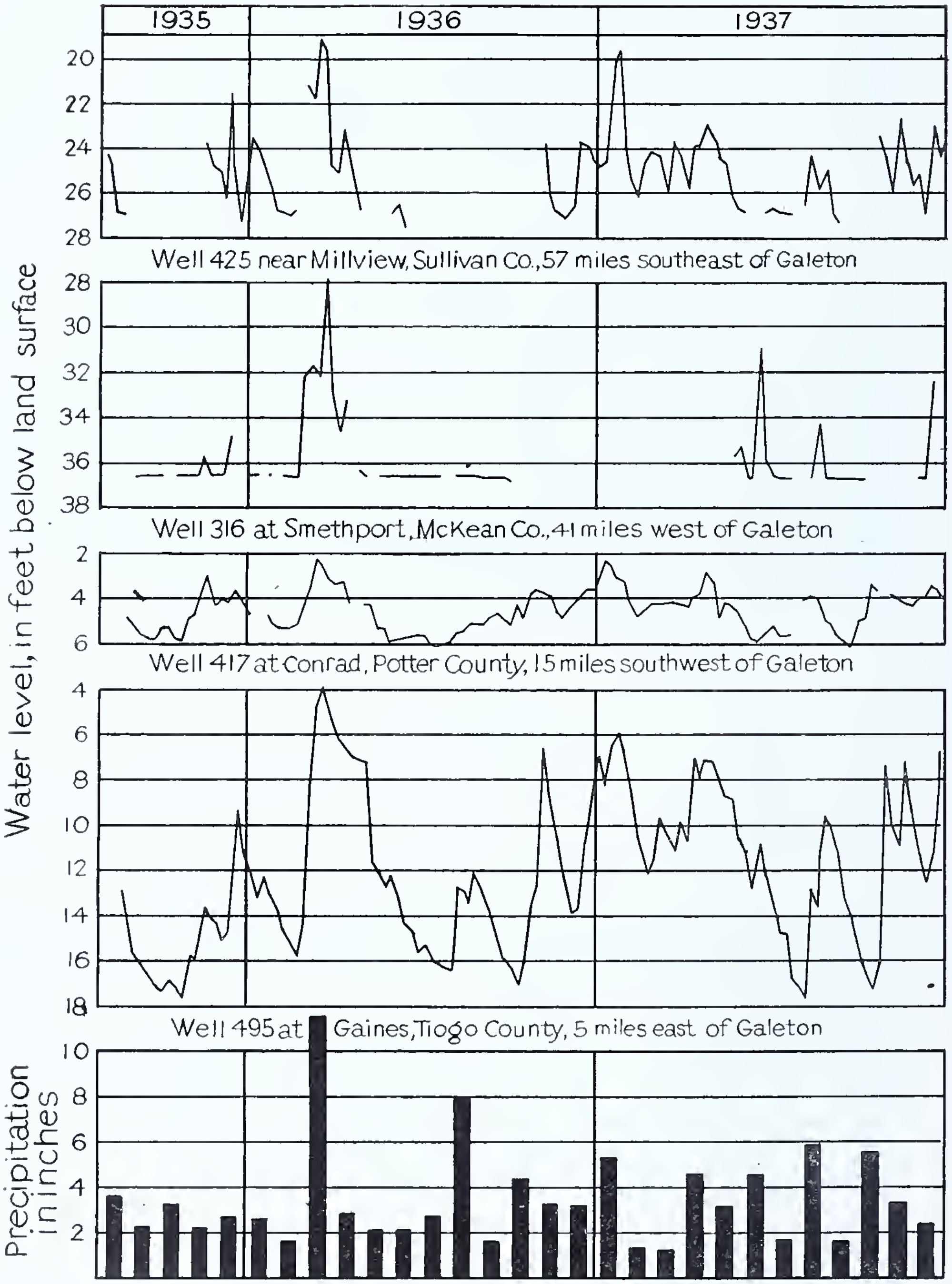


Fig. 6. Graphs showing the weekly fluctuations of the water levels in 4 observation wells in north-central Pennsylvania, and the monthly precipitation at Galeton, Potter County. Precipitation data from U. S. Weather Bureau.

uncemented brick, so that water may enter the well at any point be-
somewhat as that shown in figure 7.
neath the surface. A cross section of the well would probably look

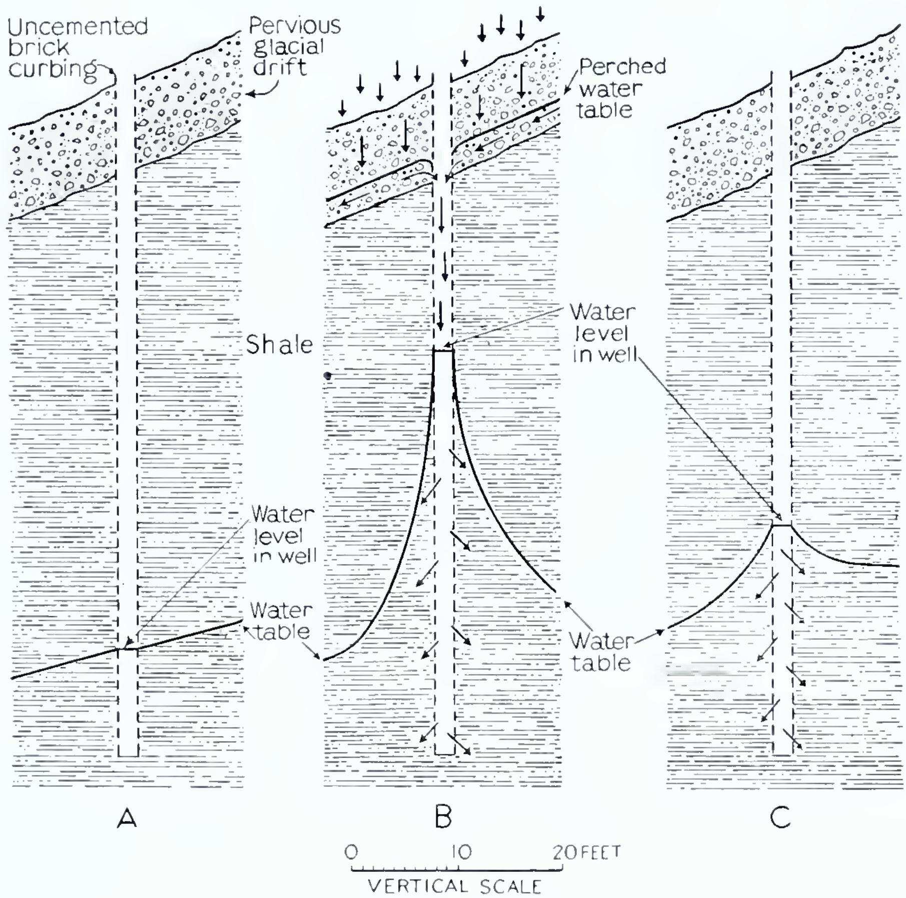


Fig. 7. Possible conditions in observation well (no. 52) at Towanda, Bradford County, at three different times of the year: A, During a dry fall when the water table is at a very low stage; B, During a rainstorm in March or April under conditions favorable for heavy recharge; and C, During a rainless period in late spring, when water stored under condition "B" is still draining slowly through the shale of low permeability. (See also figure 5.)

During a dry fall when the water table is at a very low stage the water level in well 52 probably represents the basic water table essentially in its natural condition, as shown in figure 7A. In March or April, when conditions are generally favorable for heavy recharge, a part of the precipitation percolates downward through the thin veneer of permeable material that overlies the bedrock at this locality. Upon reaching the top of the relatively impermeable shale, the downward course of the water is checked and hence a sheet of perched water is probably formed. As the uncemented brick curbing in well 52 is pervious, part of the perched water probably seeps or flows down the well in sufficient quantity to build up the water table in the shale of low permeability surrounding the well. As shown in figure 5, the

water level has risen as much as 30 feet above its minimum level. After recharge ceases, the water level in well 70 declines rapidly at first, and the rate of decline becomes less as lower water levels are reached. Figure 7C illustrates the probable conditions during one of these declines, with water in the well and part of the adjacent shale still standing somewhat above the true water table and declining at a rate depending upon difference in head and the permeability of the shale. If this well were tightly cased down to the shale, so as to cut off all of the zone of temporary perched water, the water level would probably reflect more nearly the true water-table conditions, and the annual fluctuations would probably be smaller. If the well were thus cased, it is probable that there would be a considerable time lag between the beginning of recharge and rise of the water level, as this is known to be true in many deep wells.

The general factors controlling fluctuations in the water levels in wells have been stated, and some of the additional conditions peculiar to the 6 observation wells in north-central Pennsylvania have been enumerated. To summarize, it may be stated that, other things being equal, the fluctuations in ground water levels are related primarily to the amount of recharge received from precipitation, but that the amount of precipitation necessary to produce recharge differs in different seasons of the year, with respect to the character of material in the soil and in the zones of aeration and saturation, with the depth to the water table, and under certain conditions with such factors as barometric pressure, tidal fluctuations, and others.

Reference to figures 5 and 6 shows that in north-central Pennsylvania the water levels in wells generally stand higher in March or April, which is generally the period of maximum recharge, although not the period of greatest precipitation. An exception to this occurred in 1937, when the water levels in some wells were higher in January than in March or April, as a result of the heavy precipitation that caused the great Ohio River flood in January of that year. The highest water levels on record for observation wells throughout Pennsylvania were reached in March, 1936[25], as a result of the peculiar combination of weather events that produced the record-breaking floods at that time[26].

The lowest water levels are generally reached near the end of the growing season in September or October, although the water levels sometimes continue to decline after October. The normal summer declines are sometimes arrested by abnormally heavy rains, as occurred in well 495 in August, 1936, and August, 1937, and in wells 52 and 70 in August and September, 1933. Despite the exceptionally high ground-water levels reached in March, 1936, the water levels in well 52 and in many others declined persistently during the spring and summer of that year, reaching a very low stage on October 1, because of the fact that the precipitation during this period was insufficient to

[25] Lohman, Stanley W., Ground-water levels in Pennsylvania in 1936: Am. Geophys. Union Trans., 18th Ann. Meeting, pp. 494-498, 2 figs., 1937.

[26] The floods of March, 1936. Part 2. Hudson River to Susquehanna River Region: U. S. Geol. Survey Water-Supply Paper 799, 380 pp., 12 pls., 49 figs., 1937.

produce appreciable recharge. The water levels in wells 417 and 495, however, rose somewhat from heavy local precipitation in August, 1936.

The water flowing in the streams during periods of dry weather is practically all ground water that has escaped from springs or seeps, hence as the ground-water levels in wells declines during the summer months, so also does the stream flow decline. Thus the flow of the streams in this area reached very low stages during the summer and fall of 1936, and the low ground-water levels and stream flow reached by the fall were in part the result of conditions that existed prior to May 15 and were in a measure forecast by the ground-water levels on that date. During the summer, and especially in dry periods, the vegetation in the low places adjacent to the streams makes heavy draft on the ground water and hence reduces the quantity that seeps into the streams.

Since the water discharged by springs in the area represents water that escapes from the zone of saturation, the discharge of springs also fluctuates in response to precipitation and other factors. Some residents of the area believe that the discharge of springs is absolutely constant, but if these springs were observed carefully throughout the year, it would be found that the discharge is not constant and in nearly all springs varies considerably from winter to summer. The head and discharge of many of the flowing wells in the area also varies considerably from winter to summer.

Relation of ground water to geologic structure

In many of the rock formations in north-central Pennsylvania strata of permeable rock, such as fractured sandstone, alternate with less permeable beds, such as shales. In places where the strata are tilted, water falling on the outcrop area of a permeable stratum moves down the dip between the confining layers of impermeable material and saturates the permeable stratum nearly to the surface. Under these conditions wells drilled to the water-bearing bed may encounter water which is under artesian pressure, that is, water which rises above the local water table. If the water rises high enough to flow at the surface the well is a flowing artesian well. The chief requisite conditions for artesian wells are shown in Fig. 8.

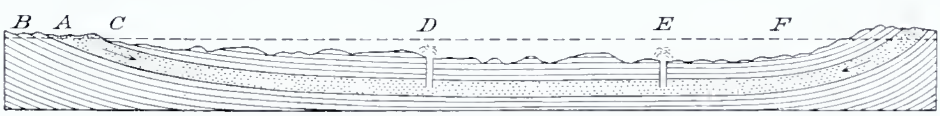


Fig. 8. Ideal section illustrating chief requisite conditions for artesian wells. A, permeable bed; B, C, impermeable beds below and above A; D, E, flowing wells from bed A; F, height of water level in permeable bed A. (After Chamberlain.)

Rock structures favorable for artesian conditions in this area are synclinal basins (Fig. 8) in which the strata on all sides dip toward a common axis or center, the flanks of anticlines, where the strata dip away from the anticlinal axis (plate 4), and tilted beds of sand or gravel confined beneath beds of clay. On plate 2 are shown 52 wells

that flow all or part the year. This does not represent the total number, however, but represents only those for which records are given. As noted in the county descriptions and in the remarks of the well tables, some of the flowing wells listed are typical of numerous flowing wells in a particular vicinity. Thus nearly all the wells in the vicinity of well 379, Harrison Valley, Potter County, are reported to flow.

Well 216, Lycoming County, is the only flowing well observed or reported in that part of the area lying in the Valley and Ridge province Perhaps the greater deformation suffered by the rocks of this province has ruptured the confining beds in most places so that any water that normally would be held under pressure beneath them escapes upward to the water table.

In most of the wells, the water, if confined, would rise only one or two feet above the land surface, but as shown in the well tables, the static head in seven scattered wells is reported to be from 5 to 25 feet above the land surface. Most of the flowing wells are reported to flow only from ¼ gallon a minute to 1 or 2 gallons a minute, but several have reported flows of 25 to 50 gallons a minute, and well 379, Potter County, is reported to flow 80 gallons a minute. Some of these wells flow perenially, but may have larger flows during the winter and spring. Others flow only during the winter and spring. Many of the industrial wells that flow are pumped to obtain more water, as for example well 338, McKean County, which flows 50 gallons a minute, but which when pumped yields 150 gallons a minute with a drawdown of 11 feet.

About ¼ of the flowing wells whose records are tabulated tap beds of sand or gravel confined beneath less permeable material such as clay or silt. The other flowing wells are in consolidated rocks. The local occurrences of flowing wells and areas where such wells might be expected are given in the county descriptions.

Several so-called "spouting wells" or "geyser wells" in southwestern McKean County were described by Ashburner[27] in 1878 and 1879. These were not flowing wells, like those just described, but were all abandoned deep test wells for oil and gas, in which natural gas pressure caused the water to spout high in the air at periodic intervals. One such well was drilled near Kane in 1878 to a depth of 2,000 feet. Considerable water encountered down to a depth of 364 feet was cased off. Some gas was found at a depth of 1,415 feet, but as oil was not found in paying quantity, the casing was pulled and the well abandoned. The water was then free to flow down the well, encountering the gas below. When the accumulating gas in the strata at the bottom built up sufficient pressure, the water would suddenly discharge in large volume for 1½ minutes, rising 100 to 150 feet into the air, and after a pause of 13 minutes, the phenomenum repeated. Wells of this type stopped spouting as soon as the gas was exhausted. No wells of this type were observed in 1935 by the writer.

[27] Ashburner, C. A., Description of the Wilcox spouting water well: Am. Jour. Sci., vol. 3, no. 16, pp. 144-147, 1878.
Ashburner, C. A., The Kane geyser well: Am. Jour. Sci., vol. 3, no. 18, pp. 394-395, 1879.

Water in unconsolidated deposits

Unconsolidated deposits of several types are found in north-central Pennsylvania, comprising glacial till, and lake and stream deposits. The history of their deposition is given under Pleistocene epoch; their thickness, character, distribution, and water-yielding capacity are described on pp. 92-97.

Till, which is unstratified material laid down directly by the glacial ice, is composed of poorly assorted material (fig. 3B), and therefore generally has low porosity and permeability, and does not yield water freely to wells. Till, where thick, may contain lenses or pipes of stratified sand or gravel, which yield water freely. Till probably supplies a few dug wells and springs in the area, but is unimportant as a source of ground water.

The lake and stream deposits were subjected to the sorting action of water, which resulted in the separation of the fine and coarse material into distinct beds of gravel, sand, silt, or clay (fig. 3A) although in some beds this separation was less distinct and finer materials occupy the pore spaces between larger particles. A coarse, clean, gravel or sand has a high porosity, high permeability, and high specific yield (the ratio of the volume of water produced to the volume of the rock yielding the water), and therefore yields large quantities of water to properly constructed wells.

Sand and gravel deposited in lakes and streams are the largest producers of ground water in north-central Pennsylvania, and supply nearly 30 percent of the wells for which records are given in the county descriptions. Plate 2 shows the distribution of these materials in the area.

Of the numerous wells ending in gravel or sand, yields in gallons a minute were reported as follows:

Wells	Gallons	Wells	Gallons	Wells	Gallons
14	less than 5	4	201-300	6	601-800
65	5- 50	10	301-400	8	870
27	51-100	2	401-500		
17	101-200	2	501-600		

Many of the wells reported to yield from less than 5 gallons to 50 gallons a minute are domestic wells for which the maximum water-yielding capacity is not known. The maximum yields obtainable from gravel or sand depends in large measure upon the methods used in constructing and developing such wells, a fact that is not fully appreciated by many well drillers and well owners in the area. The yields of many such wells in the area could be greatly increased by application of some of the methods described under Drilled Wells in Unconsolidated Deposits.

Water in sandstone, conglomerate, and quartzite

Next to gravel and sand, sandstone is the most productive water-bearing material in north-central Pennsylvania. Conglomerate and quartzite occur locally but are not as important as carriers of water in this area.

The size of grain, degree of assortment, amount and character of cementation and the amount of jointing are the principal factors that determine the water-bearing properties of a sandstone or conglomerate, and jointing is the most important factor in a quartzite. Nearly all the sandstones and all the conglomerates and quartzites in this area appear to be rather firmly cemented, so that in general their porosities are probably rather low. Those cemented with silica (SiO_2) or iron oxide (Fe_2O_3) generally retain most of their cementing material even in weathered outcrops. Those cemented with calcium carbonate ($CaCO_3$), such as those of the Oriskany group, may lose all or much of their cementing material down to appreciable depths through leaching by vadose or ground water, leaving loose sand grains. It is believed that the fairly large quantities of water yielded by most of the sandstones in this area are derived principally from joints and fractures along bedding planes similar to those shown in Plate 8B rather than from the pore spaces of the rock.

Although the cementing material greatly reduces the porosity, it makes the rock hard and brittle so that numerous joints may develop, especially in places where the rocks have suffered deformation. The cementing material also prevents loose sand grains from entering the wells and in this way may be indirectly responsible for producing better water-bearing conditions. Other things being equal, the number and size of openings in joints and bedding planes are greater generally in beds near the surface and tend to decrease with depth.

Beds of water-bearing sandstone are numerous in most of the rock formations of north-central Pennsylvania. The Pocono and Pottsville formations consist largely of sandstone and are the most productive.

Most of the wells in the area ending in sandstone, as in other types of rock, are used only for domestic purposes, so that their maximum water-yielding capacity is not known. This is also true of some municipal and industrial wells, but for many of these the yield at a given drawdown is known. Thus of wells believed to end in sandstone 43 wells were reported to yield less than 5 gallons a minute; 129 wells from 5 to 50 gallons; 172 wells from 51 to 100 gallons; 45 wells from 101 to 200 gallons; 6 wells from 201 to 300 gallons; 6 wells from 301 to 400 gallons; 6 wells from 401 to 500 gallons; and 7 wells from 501 to 600 gallons a minute.

Some wells in sandstone reported to yield less than 5 gallons a minute may not have been drilled sufficiently deep to intersect an adequate number of joints, others probably encountered dense sandstone with few or tightly closed joints, and some were drilled in places where the water table lies several hundred feet below the land surface, so that the well penetrated only a small section of saturated rock.

Most of the wells ending in sandstone with reported yields of more than 200 gallons a minute are in the Pocono formation, and all yielding more than 400 gallons a minute are in the Pocono. The strongest group of wells in the Pocono, and what may be the strongest group of wells from indurated rock in the State, is described on pages 63-66.

Water in shale

Many wells in north-central Pennsylvania obtain small supplies of water from shale, which is locally often called "slate." Thin beds of shale are present in practically all of the Paleozoic formations, even the sandstones and limestones, but the following formations or groups consist largely of shale or contain thick beds of shale: Reedsville, Juniata, Clinton, Cayuga, Hamilton, Portage, Chemung, Catskill, Mauch Chunk, Allegheny, and Conemaugh. In the county well tables, some of the wells reported to obtain water from shale or "slate" may in reality derive most of their supply from sandstones. In some other wells the nature of the water-bearing material is not definitely known.

Although shale generally has considerable porosity the pore spaces are so small that most of the water is retained in the rock and does not become available to wells. In most cases, however, the shale is more or less broken by joints and bedding planes along which water may move. In soft shales the joints generally are tightly closed since the material is incompetent under the heavy load of overlying material. In hard, brittle shales, particularly those in the Plateau province referred to by the drillers as "slates," joints are more numerous and tend to produce openings that may be comparable to those produced in sandstones. Most of the joint-openings in the shales appear to be restricted to the first 100 or 200 feet below the weathered zone and many largely disappear at depths of 300 to 400 feet.

In most places the shales supply enough water for domestic purposes, from 1 to 10 or 15 gallons a minute, but in some places less than 1 gallon a minute is obtained. Forty or fifty gallons a minute appears to be about the maximum yield obtainable from wells that are definitely known to obtain water only from shale. Of the wells reported to obtain water from shale, 9 have reported yields of 51 to 100 gallons a minute and 7 have reported yields of 101 to 300 gallons a minute. It is very likely, however, that such wells derive part of their supply from thin beds of sandstone not detected by the drillers.

Water in limestone and dolomite

Limestone, which is calcium carbonate ($CaCO_3$), and dolomite which is calcium and magnesium carbonate ($CaCO_3$ $MgCO_3$), have very similar water-bearing properties, and to laymen and drillers are both known simply as limestone or lime.

Limestone is relatively of little value as a source of water in most of north-central Pennsylvania. Ordovician, Silurian, and Devonian limestones are found in Lycoming County, but have not been exploited extensively. Thin beds of limestone occur in some of the Devonian and Carboniferous formations in the other counties, and are even less important than those in Lycoming County. In many of the counties south of the area, however, limestone is a very important source of ground water and gives rise to many large springs, a detailed account of which is given in a previous report[28].

[28] Lohman, Stanley W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 5, pp. 46-51, 63-65, 1938.

Limestone and dolomite are generally very dense and do not appear to contain visible primary openings other than minute openings in bedding places. The principal openings are secondary and consist of numerous joints that originated during the folding of the strata. Such openings permit the descent and lateral movement of vadose water. This water derived from rainfall and soil water carries in solution carbon dioxide or carbonic acid and perhaps also certain organic acids derived from decaying vegetation in the soil. As limestone and dolomite are soluble in these weak acid solutions, portions of the rock are removed along the joints and these openings gradually enlarge to form intricate networks of underground channels. In addition to the removal of material by solution, vadose streams laden with sediments may remove some material by corrosion. As the channels enlarge, caverns are formed, and enlarged vertical holes called sink holes connect the caverns with the surface.

In their descent to the water table vadose streams seek lower levels and in many places leave dry channels above. Other dry channels are formed by the lowering of the water table produced by regional uplift or by the down-cutting of the streams. Redeposition of limestone takes place in many of these dry channels or on the roofs of wet channels to form dripstone or flowstone.

By the process outlined above a system of underground drainage may be developed which is comparable to a surface drainage system. The underground streams, like the surface streams, become adjusted to the base level of the streams into which they discharge and tend to become graded to this base-level. In Nippenose Valley, Lycoming County, Antes Creek and numerous small streams disappear into sink holes, follow underground channels for distances of a few hundred feet to several miles, and reappear to form Nippono Spring, with a measured discharge during a dry season of 2,300 gallons a minute (see spring 225, Lycoming County). There is a similar spring in Mosquito Valley, whose discharge is not known.

In addition to the solution of limestone by vadose water above the water table, limestone is also dissolved by ground water at the fluctuating top of the water table and for a small distance below the water table, for there is generally free circulation at these levels.

In jointed folded limestones that contain relatively impervious confining layers of clay or shale, deep seated artesian circulation may take place and in this way it is possible to form solution channels at considerable depth below the water table.

The success of a well in limestone or dolomite depends upon the number, size, and water-bearing capacity of the solution channels encountered. As the positions of such openings can but rarely be inferred from surface conditions, there is always some uncertainty as to the success of a new well. Wells that encounter one or more water-filled channels generally yield large supplies of water, wells that encounter no such openings yield little or no water. It is deemed unwise to drill in limestone or dolomite more than 350 feet below the local water table in nearby wells or the local drainage level in nearby

perennial streams. If a satisfactory supply is not obtainable within this depth, it is generally more desirable to drill a new well a short distance away.

Clay, sand, and rock debris carried by vadose streams are encountered in solution channels above the water table in some wells, and these should be cased off together with all other openings above the water table, since they constitute a potential source of contamination. In some wells, solution channels below the water table contain residual clays, and if such channels are pumped heavily, the water may be muddy.

Records were obtained of only 5 or 6 wells getting water from limestone in the Cayuga group and from the Helderberg limestone, 5 of which were reported to yield from 5 to 50 gallons a minute, and 1 of which was reported to yield 150 gallons a minute. No records of wells were obtained in Nippenose and Mosquito Valleys, Lycoming County, the only large valleys in the area underlain entirely by limestone, as most of the residents in these valleys obtain softer water from cisterns or from springs in the surrounding mountains.

Water in coal

Beds of coal occur in the Pottsville, Allegheny, and Conemaugh, formations but in this area are most abundant in the Allegheny formation in Elk County.

As coal is brittle it is readily jointed, generally along bedding planes and at right angles to these planes similarly to shales and "slates." In many places coals are underlain by impervious underclays or shales which help to retain the water.

Coal is unimportant as a source of water in this area, and no wells were observed or reported to obtain water from it. In some places coal beds can be traced by small contact springs or damp places along their outcrops. Some of these springs doubtless issue from the coal beds, the water being held above the impervious underclays. In some cases, however, the water may issue from permeable shale or sandstone overlying the less permeable coal.

Large quantities of ground water are encountered in the larger coal mines of the area, which must be pumped or drained from the mines. Part of this water occurs in the coal beds, and part of it probably drains downward from overlying sandstones or "slates." In a small mine visited in the McIntyre coal field of Lycoming County, about 100 gallons a minute was being disposed of, most of which came from the coal bed being mined.

Water from undisturbed coal beds may be potable and not highly mineralized, but water from coal beds that have been exposed to air in or near mines generally contains hydrogen sulphide, iron, and in some places sulphuric acid. (See Quality of water). For this reason, many wells in Elk County that penetrate coal beds but obtain water from other materials below the coal, are cased down to a point below the lowest coal encountered. Where highly acid waters are encountered,

ordinary iron or steel casings are apt to be badly corroded unless they are protected in some way. In well 135, Elk County, the 200 feet of double casing is protected by an annular layer of cement.

RECOVERY

GENERAL FEATURES

In north-central Pennsylvania ground water is recovered principally from drilled wells. Some water is recovered from springs, dug wells, caisson wells, driven wells, and in one place from an infiltration gallery.

When water is withdrawn from a well there is a difference in head between the water inside the well and the water in the material outside the well. The water table or pressure-indicating surface in the vicinity of a well that is discharging water has a depression somewhat in the form of an inverted cone, the apex of which is at the well, as illustrated in figure 9. In artesian conditions the cone of influence

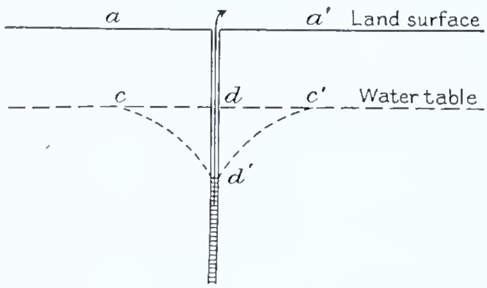


Fig 9. Diagrammatic section of a well that is being pumped, showing its drawdown (dd'), cone of influence (cc'd'), and area of influence (aa'). (After O. E. Meinzer.)

exists only as an imaginary cone whose apex is the point of discharge of the well. In any given well, the greater the pumping rate the greater will be the drawdown and the greater will be the diameter of the cone of influence and the area of influence. If the well is heavily pumped the water levels in wells several hundred feet or even a few miles away may be lowered somewhat.

The specific capacity of a well is its rate of yield per unit of drawdown, and is usually stated in gallons a minute per foot of drawdown. For example, well 256 in McKean County is reported to yield 635 gallons a minute with a drawdown of only 4 feet. Its specific capacity therefore is about 159 gallons a minute per foot of drawdown. Wells in some of the consolidated rocks such as shale may have yields of less than 1 gallon a minute per foot of drawdown.

When a well is pumped the water level drops rapidly at first and then more slowly, but may continue to decline for several hours or days. Therefore, in testing the specific capacity of a well, it is important to continue pumping until the water level remains approximately stationary. When the pump is stopped, the recovery is likewise rapid at first, but tapers off slowly and may continue long after pumping has ceased.

Obviously, since the cost of pumping water increases with the draw-down, material saving in the cost of pumping can be effected by increasing the specific capacity of a well by modern methods of well construction, some of which are described below under Drilled wells in unconsolidated deposits.

SPRINGS

In north-central Pennsylvania, many of the domestic supplies, a few of the industrial supplies, and most of the public ground water supplies are obtained from springs. Small springs are numerous in most of the counties, especially north of the glacial borders (plate 1), and a few large springs are found in the limestone valleys of the Valley and Ridge province.

Most of the springs in this area are gravity springs; the water does not issue under artesian pressure but is due to an outcrop of the water table. The water from these springs percolates from permeable material or flows from openings in rock formations, under the action of gravity, somewhat as a surface stream flows down its channel.

The gravity springs may be further classified as seepage springs, in which the water percolates from numerous small openings in permeable material; as fracture springs, in which the water flows from joints or other fractures in the rocks; or as tubular springs, in which the water flows freely from large channels in soluble rocks. The distinctions between these types of springs are somewhat arbitrary and all may grade into one another in some cases.

With respect to the quantity of water discharged, Meinzer[29] has devised the following classification of springs for convenient use in the United States.

Meinzer's classification of springs with respect to discharge

Magnitude	Discharge	Magnitude	Discharge
First	100 second-feet or more	Fifth	10 to 100 gallons a minute
Second	10 to 100 second-feet	Sixth	1 to 10 gallons a minute
Third	1 to 10 second-feet	Seventh	1 pint to 1 gallon a minute
Fourth	100 gallons a minute to 1 second-foot (448.8 gallons a minute)	Eighth	Less than 1 pint a minute (less than 180 gallons or about 5 barrels a day)

In north-central Pennsylvania there are no springs of first magnitude, and probably none of the second, but there is one spring of at least third magnitude and many of the fourth magnitude. The largest are tubular springs in limestone.

Most of the springs in the area are seepage springs of fourth magnitude or lower. Many of these are contact springs, in which the water flows to the surface through permeable material over the outcrop of impermeable or less permeable material that prevents the downward

[29] Meinzer, O. E., Outline of ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 494, p. 53, 1923.

percolation of the ground water and thus deflects it to the surface. The strongest springs of this type in the area issue from beds of sand or gravel in the glaciated region. Many of these spring flow from 50 to 100 gallons a minute, a few flow as much as 200 gallons a minute, and two of the springs near Coudersport, Potter County, are reported to have a combined flow of 2 million gallons a day or nearly 1,400 gallons a minute. Contact springs issuing from rock are common on the hillsides in the Plateaus province, where nearly horizontal beds of clay, shale, or coal form the barriers which bring the overlying water in jointed sandstones or shale to the surface. Most of these springs flow less than 50 gallons a minute. Small seepage springs are also found on the hillsides in the Valley and Ridge province, particularly along slopes covered by talus from the Ordovician and Silurian sandstones. Springs of this type are utilized by many residents of Nippenose and Mosquito Valleys, in southern Lycoming County.

Depression springs, whose waters flow to the surface from permeable material simply because the surface extends down to the water table, are found in some parts of the area, particularly at the heads of perennial streams in upland areas, and along the major stream channels.

The largest known spring in the area is Nippeno Spring (no. 225) in Lycoming County. This is a tubular spring that issues from a large solution channel in Ordovician limestone. It discharges practically the entire underground drainage of Nippenose Valley, and, on Oct. 1, 1932, during a dry period, had a measured discharge of 2,300 gallons a minute, classifying it as of third magnitude. The discharge of this spring during wet seasons is not known, but may reach second magnitude. There is a similar, but probably smaller spring in Mosquito Valley, but the discharge is not known. Numerous large tubular springs in south-central Pennsylvania have been described[30].

Some of the springs in this area are listed with the tabulated well records for Bradford, Lycoming, Potter, and Sullivan Counties, and others are noted in the descriptions of public water supplies in the county descriptions.

WELLS

Dug Wells

In some of the rural regions dug wells are still used for domestic and stock supplies. Many of them obtain water from rather poor water-bearing material, but because the diameter of the wells is large, great infiltration area and considerable storage of water are provided. Dug wells are more apt to fail during dry seasons and are more subject to contamination than the deeper drilled wells. Dug wells are generally curbed with stone, brick, or wood, but some are curbed with tile or concrete. Most dug wells for domestic use are from 1½ to 3 or 4 feet in diameter but some dug for industrial use are 18 to 25 feet or more in diameter and are commonly called caisson wells.

In constructing a caisson well, the large cylindrical caisson (generally of concrete) is built on the surface of the ground, and the

[30] Lohman, Stanley W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 5, pp. 63-65, 1938.

material inside is removed by means of a "clamshell" or "orangepeel bucket," allowing the caisson to sink into the excavation. As a section of caisson sinks below the surface of the ground, additional sections are added at the top until the excavation and caisson have been sunk to the required depth. Several wells of this type have been built in the area for obtaining large quantities of water from sand and gravel beds (see well 211, Lycoming County), and there are a few large dug wells. The 8 dug wells of the Williamsport Water Company (no. 208, Lycoming County) are reported to yield about 870 gallons a minute each, the strongest yields reported in north-central Pennsylvania.

Some dug wells that have gone dry or failed to yield adequate supplies have been deepened by drilling, and are listed in the county tables of well records as dug and drilled wells.

Driven Wells

In some of the valleys containing lake or stream deposits (pl. 2) driven wells are used for domestic or stock supplies. Driven wells can be used only where the materials are soft enough to permit a pipe being driven and where the material is sufficiently permeable. They generally consist of a 1¼- or 1½-inch pipe with a screen-covered drive point at the bottom. As in the case of dug wells, driven wells are more apt to fail during dry seasons because they do not extend very far below the water table and furthermore, they are more subject to contamination than the properly constructed drilled wells of greater depth.

Drilled Wells

Most of the industrial and public ground-water supplies and a large part of the domestic supplies are obtained from drilled wells. All of the drilled wells observed or reported in the area were drilled by percussion methods, chiefly by the portable cable-tool (or solid-tool) method. Wells drilled for domestic use are generally 6 inches in diameter (casing 5⅝ inches inside diameter). Those drilled for industrial or municipal use are generally 8, 10, or 12 inches in diameter, although a few may be larger.

Drilled wells in consolidated rocks.—The drilled wells in this area that obtain water from the consolidated rock formations are cased through the overlying weathered rock or unconsolidated deposits with casing that is driven several feet or more into the bedrock. Therefore the water may enter the well along its entire uncasd portion wherever the rock is water-bearing. Wells finished in this way are called open-end wells because the water enters only below the lower end of the casing. In some places where it may be desirable to case off undesirable water in coal beds or to case off dry or clay-filled solution channels in limestone, the casing is carried down through the bedrock until more favorable conditions are found. A well of this type may require one or more reductions in the diameter of the hole as drilling proceeds, and several casings of different diameter. The yields of drilled wells in the different consolidated deposits are discussed under Occurrence of Ground Water.

Drilled wells in unconsolidated deposits.—Many of the drilled wells in the area that obtain water from unconsolidated material (sand or gravel) are cased to the bottom and receive water only through the open end of the casings. In others, however, the intake area and consequently the efficiency has been greatly increased by one of the methods described below.

The simplest way to increase the intake area is by perforating those portions of the casing that are opposite the water-bearing beds. In drilling such a well samples of material should be taken every few feet, and the depth and thickness of water-bearing beds carefully recorded, in order to know where to perforate the casing and to permit the selection of the proper size for the perforations. A more efficient method of increasing the intake area of a well is by the use of well screens. Well screens (or strainers) are manufactured in many different types and sizes. The grain size of the water-bearing material determines the size of openings to be used in the screen. Some well screens are surrounded by an annular layer of carefully selected gravel. This is commonly used in fine-grained material, for by increasing the diameter and intake area of the screen with a layer of gravel, the velocity of the incoming water may be reduced sufficiently to prevent the finer material from entering the well.

Examples of good well construction in sand and gravel are the two wells of the Bradford Municipal Water Company, the logs and construction details of which are shown in figure 10. The procedure followed in constructing these wells is briefly as follows. First an 18-inch hole was drilled and cased, a record being kept of the types of material penetrated. Inside the 18-inch casing was set, opposite the best water-bearing material, a well screen 12 inches in diameter to which was attached an upper section of blank 12-inch casing. The bottom of the well screen was closed with a concrete plug. Carefully selected clean gravel of uniform size was poured into the annular space between the two casings, filling the entire space. The outer 18-inch casing was then jacked up a few feet at a time, while the water in the well was being alternately pumped out and agitated. This process continued for 4 to 6 days, with the addition of more gravel as needed, until the outer casing had been jacked up to the top of the screen. Seven tons of gravel were thus placed in well 255 and 6 tons were placed in well 256. After pumping each well at the rate of 635 gallons a minute for 8 hours, the drawdown in well 255 was 6 feet and that in well 256 was only 4 feet. By using larger pumps, thus increasing the drawdown somewhat, each well would probably yield 1,000 gallons of water a minute or more.

Although such methods of constructing and developing screened wells in sand or gravel have been known for many years, there are surprisingly many examples of poor well construction in the area. In some places attempts have been made to obtain large quantities of water from wells cased to the bottom, so that they receive water only through the hole at the bottom of the casing. This generally results in a greater drawdown, and if the well is pumped at too high a rate, sand is generally pumped with the water. In other wells, improperly slotted

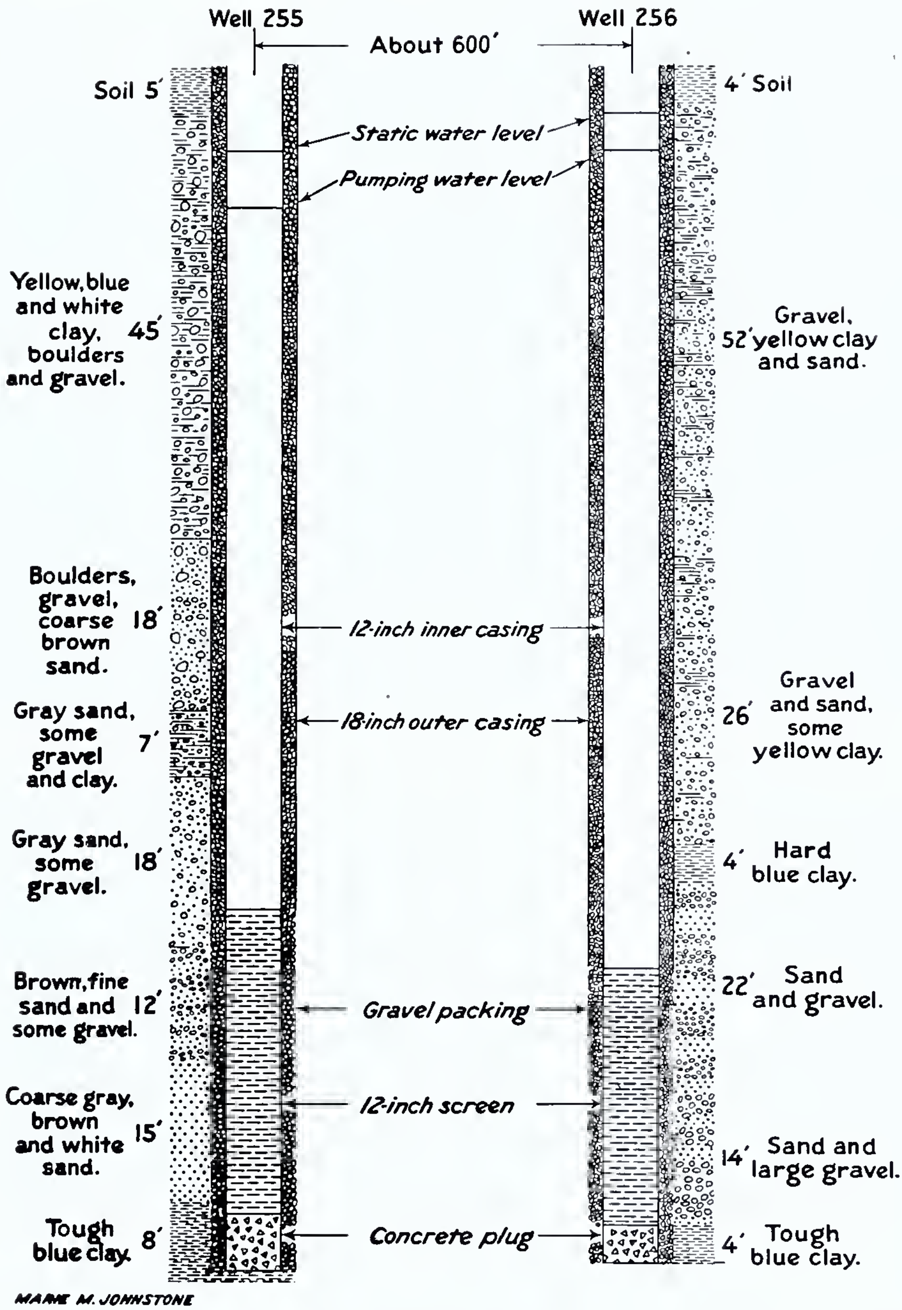


Fig. 10. Logs and construction details of two wells of the Bradford Municipal Water Company, near Bradford, McKean County.

casing or home-made screens have been used, which have gradually clogged after a few years use, reducing the yield and increasing the drawdown. Obviously, as the cost of pumping water from wells increases with an increase in drawdown, material saving in the cost of pumping will result if the efficiency of a well can be increased. In

most of the sand and gravel-filled valleys shown in Plate 2, large quantities of water can generally be obtained from properly constructed wells.

METHODS OF LIFT AND TYPES OF PUMPS

Water is obtained from most of the dug wells and many of the drilled wells by means of hand-operated lift pumps or force pumps. The cylinders or working barrels in lift pumps and force pumps are similar and are located below the ground surface either above or below the water surface, but a lift pump is capable of discharging water only at the pump head, whereas a force pump can raise water above this point—as to an elevated tank. Some of the lift pumps and force pumps are equipped with pump jacks driven by gasoline engines, electric motors, or windmills. Pitcher pumps are used on some dug or driven wells where the water level is within the suction limit. Some dug wells are equipped with bucket pumps or chain pumps, which consist of crank-operated sprockets containing endless chains to which are attached buckets or gaskets. In bucket pumps the buckets dump the water into a reservoir in the head of the pump whence it flows out the discharge pipe. In chain pumps the gaskets fit into a vertical metal or wooden pipe, so that a continuous column of water rises to the discharge pipe when the sprocket is rotated. Pneumatic systems are widely used, in which the water is forced against air pressure into an air-tight tank, from which it flows under pressure to any part of the house.

Many types of power-driven pumps or lifting devices are in use on the industrial and municipal wells of the area. Most of the older installations consist of single or double-acting reciprocating force pumps installed in the well, or of suction pumps placed at the surface, driven by electricity, steam, or internal-combustion engines. Some of the older wells are pumped by air lift. In this method compressed air is forced through a nozzle submerged some distance below the water level, and the resulting mixture of water and air, being of less density than ordinary water, is carried to the surface, where it is discharged. In some wells where considerable drawdown is experienced, or where the water level is at considerable depth, air lifts of two or three stages are used, in which two or three air pipes of different lengths are used alternately, so that the one in use will always be sufficiently submerged. High efficiency is generally not obtainable in an air-lift system.

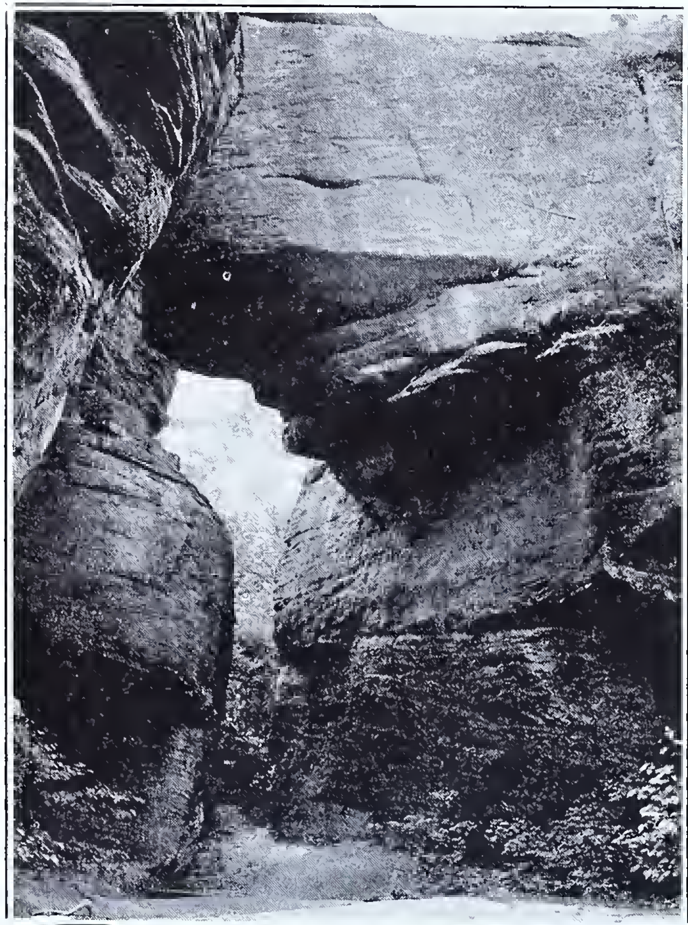
Many of the newer installations consist of electrically driven centrifugal or turbine pumps, both of which operate at high efficiency. Centrifugal pumps are mounted at the ground surface or in pits and can be used only where the depth to water plus the drawdown does not exceed the working suction limit. Deep-well turbine pumps are used in wells with greater depth to water or greater drawdown. Connected turbines called bowls or stages (the number of such units depending on the height the water must be forced) are submerged below the water level (or just above in some cases) and are connected by a vertical shaft to a vertical motor or pulley at the top. A turbine pump is shown in plate 9A.

A. Reservoir, filtration plant, and one auxiliary drilled well of the Johnsonburg Borough Water Company, Johnsonburg, Elk County.

B. Typical pump jack on an oil well in the Bradford oil field, near Rew, McKean County. Water-re-pressuring well in background indicated by arrow.

PLATE 10

A. Two drilled wells and walking-beam pumping mechanism of the Wilcox Water Company, Wilcox, Elk County.



B. Olean conglomerate member of the Pottsville at the type locality near Rock City, Cattaraugus County, New York.

In and near the oil fields, some water wells are equipped with pump jacks of the Pennsylvania oil-field type, one of which is shown in plate 9B. A group of wells thus equipped may be pumped from a central source of power through radiating cables or rods that lead to each well. Four water wells in Potter County (no. 359) are pumped in this manner. An adoption of a method used in drilling and also in pumping oil wells is shown in plate 10A, in which the pump rods of two identical water wells are attached to the ends of a typical walking beam pivoted on a central Samson post. The weight of the pump rods in one well is just balanced by those in the companion well, and the reciprocating motion is transmitted to the walking beam by a pitman and crank driven by a Diesel engine.

INFILTRATION GALLERIES

An infiltration gallery or tunnel is an artificial tunnel that extends laterally into the zone of saturation and through which water flows by gravity to the surface. The only supply visited in this area that might be classed as an infiltration gallery, is that of the Troy Borough Water Company in Bradford County (no. 29). In its construction, a ditch about 150 feet long was dug in glacial sand and gravel along a gentle slope at a place where a spring had existed. The lower end of the ditch is level with the surface, and the upper end is about 12 feet below the surface. A well 6 feet deep curbed with 18-inch tile and several wells twelve feet deep cased with 6- and 8-inch pipe were sunk below the bottom of the ditch. As the tops of all wells lie beneath the water table, there is a continuous flow upward from each well into the ditch, whence the water flows down the ditch to a collecting basin. The total discharge is about 140 gallons a minute.

UTILIZATION

RELATION TO TOPOGRAPHY

As the cultural development of the area is confined in general to the valleys, it follows that the development and utilization of ground-water supplies also are confined generally to the valleys, although some supplies are developed on ridges or hillsides and some so developed are piped for utilization in the valleys below.

In the Plateaus province, where the strata are only gently folded, the valleys have been cut down through hard and soft beds alike, so that the particular water-bearing formations that may be encountered beneath a given valley depends upon the depth to which the stream has cut. Since there are many different valleys cut to many different depths in this province, water-bearing beds in each of the geologic formations are utilized at one place or another. Fortunately, the Pleistocene lake and stream deposits, the most productive water-bearing materials in the area, occupy most of the valleys in the area.

In the Valley and Ridge province, however, where the strata have been severely folded, the principal valleys are cut in the softer rocks, such as shale and limestone, and the ridges are the up-turned edges of hard resistant sandstones, so that the development and utilization of ground-water supplies from the consolidated rock formations are

largely from the valley-forming rocks—that is, shale and limestone. Thus, in this province a limited number of geologic formations furnish most of the ground-water supplies to wells tapping bedrock and the remainder, which form ridges, are not accessible to widespread exploitation.

The uses of ground water in this area are many. In the tabulated data in the county chapters of this report, the uses of ground water are divided principally as follows: cooling or condensing, domestic, industrial, public supply, and livestock. In addition, some supplies are further classified as: bottling, irrigation, flooding wells for oil recovery, railroad, swimming pool, and washing automobiles. The principal uses are described below.

DOMESTIC SUPPLIES

Practically all of the domestic supplies in rural areas and in towns or villages which have no public-water supplies are obtained from wells, or springs. At first springs and dug wells were used, but in later years drilled wells became more popular. In 1935 most of the good springs were in use. Dug wells have gradually fallen into disfavor because they are subject to pollution and are apt to fail in dry weather. Some dug wells that have failed have either been deepened by drilling or abandoned altogether and replaced by drilled wells. Practically all new wells put down in the area are drilled.

The domestic use of water generally includes drinking, cooking, washing, and, in modern houses, the disposal of sewage. Water from some wells or springs may be dangerously polluted and care should be taken to avoid such water or remove the source of the pollution. In this area the ground waters are generally satisfactory for all domestic purposes, although some contain objectionable amounts of iron, sodium chloride (common salt), or hydrogen sulphide and some are so hard as to be unsuitable for use in washing (see Quality of Water). In the limestone valleys where the water is quite hard, cisterns are used extensively to supply soft water for washing.

A few private homes and nurseries use water from drilled wells for irrigating flowers or plants, but very little irrigating of any kind is practised in this area, as the rainfall appears to be adequate for most crops. At least one swimming pool in the area is filled with water from a drilled well (no. 326, McKean County). Many farms having springs use ground water to cool milk and other dairy products.

LIVESTOCK SUPPLIES

On many of the farms that are favorably situated, small streams or springs furnish adequate livestock supplies. On other farms dug or drilled wells at the barns are used. No ground-water supplies were reported to be unfit for stock.

INDUSTRIAL SUPPLIES

Ground water is used by many industries in north-central Pennsylvania for many different purposes. For some industrial purposes water

must be of a certain chemical character, for some it must be clear, and for others its temperature is the most important factor.

The principal industrial use of ground water in this area is for cooling and condensing. Nearly all the ice or refrigerating plants, breweries, milk condensaries, cheese factories, and dairies in the area use ground water for cooling, chiefly from drilled wells but in part from springs. Some ground water from wells is used for air-conditioning theaters and office buildings, and it is likely that in the future many more wells will be drilled for this purpose. The great advantage of ground water for cooling is not only its relatively low temperature, but its uniform temperature throughout the year, which approximates the mean annual temperature of the air. The average temperature of the water in 46 representative wells and springs located in all parts of the area (see county tables) was found to be exactly 51°F. The temperature of the water in well 405, at an altitude of 2,450 feet, in Potter County, was only 46°F., that in well 106, at an altitude of 2,040 feet, in Elk County, was 47°F. The temperature of the water in 7 wells and springs at altitudes chiefly above 2,000 feet was only 48°F. On the other hand, the water in 2 wells and one spring had a temperature of 58°F. Most of the waters, however, ranged in temperature from 50° to 53°F. Moreover, the temperature of the water in any one well or spring probably does not vary more than 2° or 3° during the year. In contrast, the temperature of surface water may range during the year from less than 40° to more than 80°. In general, the chemical character of water used for cooling is unimportant, but the water in a few wells used for this purpose contains so much iron as to clog the condenser pipes at frequent intervals.

Considerable ground water is used in this area for boilers. Water for this purpose should be relatively free from foam and scale-forming constituents. Over much of the area the ground water is suitable for boiler use, but in some places the water requires treatment for reduction of hardness, and in some areas, such as the limestone valleys, the ground water is probably too hard to be economically softened for boiler use.

The manufacture of paper requires large quantities of water, a requirement being that the water must be clear. The only representative of this industry in the area is the Castanea Paper Company, at Johnsonburg, Elk County. During most of the year all processing water is obtained from the East Branch of the Clarion River, the average daily consumption being 15,000,000 gallons. As an emergency supply for use during periods when the river supply is inadequate or otherwise unsuited, the Castanea Paper Company has developed the largest industrial ground-water supply in the area, comprising an aggregate of 153 drilled wells, divided among 3 well fields, shown in figures 11, 12, and 13.

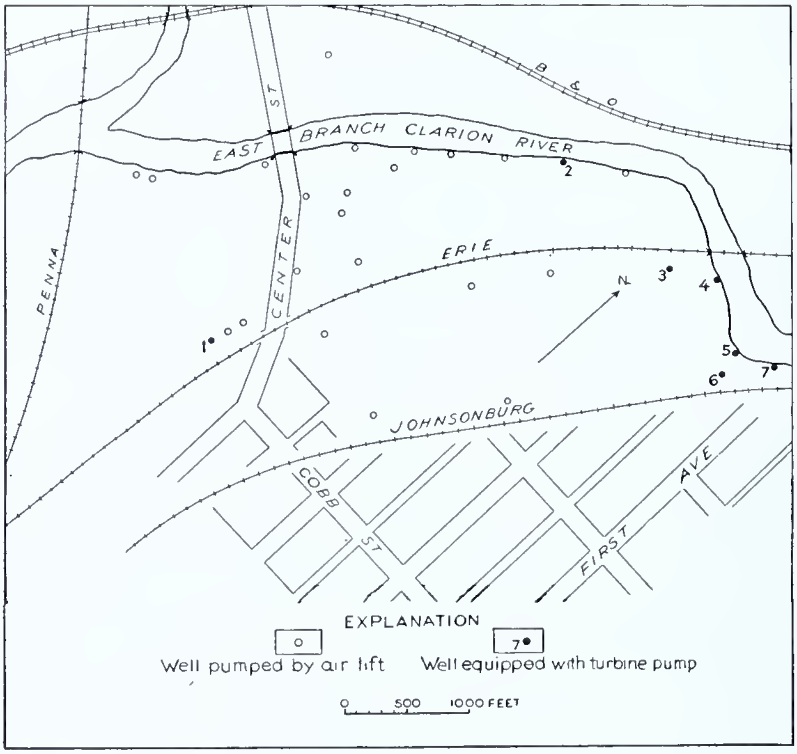


Fig. 11. Mill Yard well field of the Castanea Paper Company, at Johnsonburg, Elk County.

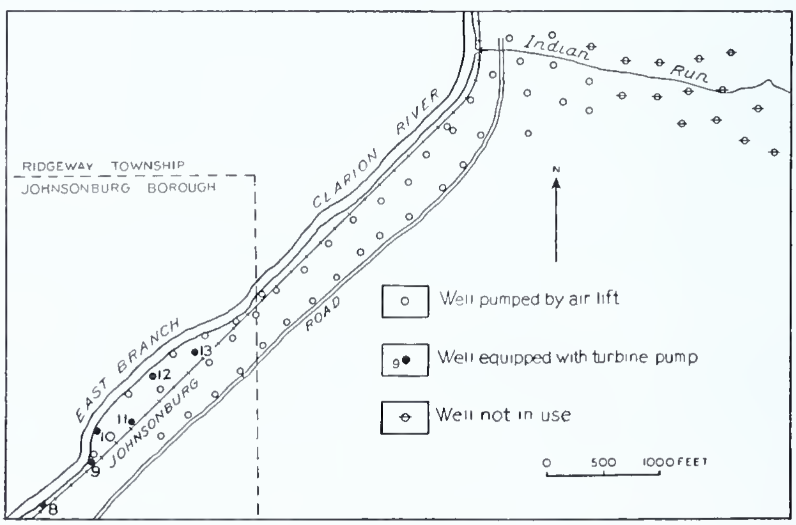


Fig. 12. Indian Run well field of the Castanea Paper Company, in and near Johnsonburg, Elk County.

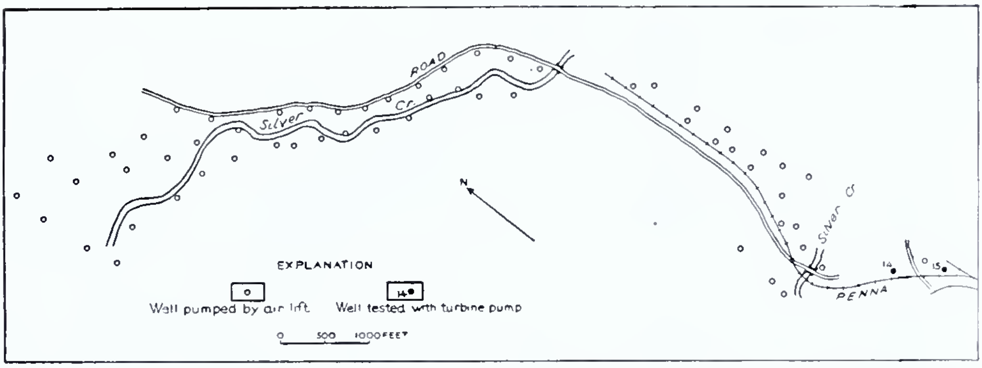


Fig. 13. Silver Creek well field of the Castanea Paper Company, northwest of Johnsonburg, Elk County.

Owing to deficient rainfall and hence stream flow in 1931, it was necessary to pump all of the wells continuously from May 15, 1931, to February, 1932. During this period the wells supplied about 83 percent of the water used. When the plant was visited in September, 1935, all processing water was being obtained from the river, and only 1 or 2 wells were being pumped to furnish water for cooling purposes. All of these wells obtain water from sandstone of the Pocono formation, and as indicated in the figures, all but 15 of the wells are pumped by air lift. The ranges in size, water level, and yield of these wells are summarized in the records of wells 121-123, Elk County. At first all wells were pumped by air lift, but owing to the great number of wells, length of air line, probable inadequacy of the air compressors, and general inefficiency of the air-lift principle, the average yield per well was only 60 to 75 gallons a minute. Moreover, it was not practicable to pump the wells shown as not in use in figure 12, as the water level in these wells stood too far below the land surface. Later several wells in each well field were tested with turbine pumps, with the results shown in the table on p. 66.

As shown in the next table, 14 of the 15 wells tested yielded 300 to 600 gallons a minute with moderate drawdown, and 7 wells yielded 550 to 600 gallons a minute, with drawdowns of only 15 to 30 feet. This is probably the strongest group of wells in consolidated rock in the State. Had turbine pumps been available when the development was first begun, only a fraction of the total number of wells would have been required. It is obvious that additional water requirements of the company can readily be met by installing additional turbine pumps in more of the existing wells. Unfortunately, the water from these wells contains considerable iron, which must be removed before it can be used in processing.

Large quantities of ground water are used in McKean County, for recovering oil from the Bradford oil sand by the water-flooding process. Without this aid to oil recovery, the Bradford pool probably would have been considered exhausted years ago, but with this method continued production appears to be assured for many years. In this

Records of drilled wells of the Castanea Paper Company at and near Johnsonburg, Elk County

No.	Depth of well (feet)	Diameter of well (inches)	Depth to which well is cased (feet)	Depth to water level (feet)	Date of measurement	Yield (gallons a minute)	Draw-down (feet)	Remarks
Millyard well field, fig. 11; well 123, pl. 2.								
1	230	6	----	28.0	Aug. 19, 1930	300	60	Water slightly salty, used only for cooling.
2	158	7⅝	----	28.0	Aug. 29, 1930	550	15±	
3	158	12	----	35.0	Aug. 27, 1930	450	50±	
4	141	12	----	----	----	350	50±	
5	151	8	----	----	----	500	15	
6	237	12	----	12-15	1935	600	30	
7	153	8	----	12	1935	550	15	
Indian Run well field, fig. 12; well 121, pl. 2.								
8	201	10	40±	15±	1935	550	15	Tested 5 to 12 hrs.
9	205	10	40	15±	1935	550	15	do
10	200	8	42.5	6.0	1930	550	15	do
11	200	8	42	6.0	1930	550	15	do
12	266	10	50.1	15±	1935	250	200	Not used
13	205	10	41.5	15±	1935	400	50	Tested 5 to 12 hrs.
Silver Creek well field, fig. 13; well 122, pl. 2.								
14	151	8	13.3	14.3	----	400	18	Tested 14 hrs.
15	152	8	27.0	4.0	----	400	16±	Tested 16 hrs.

method, a regular grid system of oil wells and water-flooding wells is put down, generally arranged according to either the "five-spot" or "seven-spot" plan. In the more commonly used five-spot plan, there are 4 water-flooding wells at the corners of a square 300 feet on a side, with one oil well in the middle. When this unit is repeated over a large lease, it can be seen that there will also be an equal number of other units with 4 oil wells at the corners of a square with one water-flooding well in the middle. In the seven-spot plan, a unit comprises 6 water-flooding wells in the shape of a regular hexagon, with one oil well at the middle.

According to Mr. Warner,[31] of the Forest Oil Company, Bradford, the water-flooding wells are drilled in the same manner as the oil wells, and extend about 25 feet into the Bradford oil sand. A 4½-inch perforated casing is set in the oil sand, connected at the top by a packer to a heavy 1½-inch water pipe which extends to the surface. A cement seal is generally placed around the water pipe above the packer. When the field is completed, water is pumped into each flooding well at a surface pressure of about 800 pounds per square inch, which, in a well 1,500 feet deep, would give a bottom-hole pressure of about 1,450 pounds. The flooding wells described by Mr. Warner each received about 1,260 gallons of water a day. In the "delayed-flooding procedure," water is pumped into the sand for 3 or 4 months before any oil is withdrawn. By this method oil wells formerly yielding only one barrel of oil a day have increased in 8 months to 28 barrels a day, and in about 8 months salt water begins to be produced with the oil. A view of a typical oil well in a "flooded" lease is shown in plate 9B, in which the well in the foreground is pumping oil and salt water, and fresh water is being pumped down the flooding well in the background.

In order to supply the large amounts of water needed for this procedure, many wells have been drilled in McKean County. Unfortunately, many relatively poor wells had been drilled in the consolidated rock formations, before it was learned that much stronger wells could be put down in the Pleistocene lake and stream deposits which fill the valleys of McKean County (plate 2). In 1935 many strong wells in gravel were pumping water for flooding purposes. The water used in flooding must be free of iron. Locally the gravel waters in McKean County contain considerable iron, which must be removed, or another source of water sought. One company has developed a group of strong gravel wells along the Allegheny River Valley at Olean, New York, with a potential yield of 10,000,000 gallons daily. The water is piped into the companies' leases in the Bradford field in Pennsylvania, and the surplus water is sold to other companies. Many more wells could be developed for this purpose in McKean County, if the proper methods of construction were followed.

There are many other industrial users of ground water in this area, including tanneries, chemical plants, meat-packing plants, and others.

[31] Oral communication, Sept. 6, 1935.

RAILROAD SUPPLIES

Railroads use water principally for drinking and for locomotive boilers. Probably most of the water used for drinking on trains in the area is obtained from the public water supplies of the large communities. The requirements of water for locomotive boilers are the same as those discussed above for industrial boiler use.

Most of the steam railroads in the area use surface water almost exclusively for their locomotive boilers. However, the Pennsylvania Railroad has wells at Port Allegany (well 298) and Larabie, McKean County, and spring 31 in Bradford County, and the New York Central Railroad has two drilled wells in Tioga County (wells 509 and 535) that supply locomotives satisfactorily.

PUBLIC SUPPLIES

At least 52 communities in north-central Pennsylvania have public water works. Of this number, 25 are supplied exclusively with ground water, 14 are supplied with surface and ground water, and 13 are supplied exclusively with surface water. Most of the 39 communities supplied wholly or partly with ground water utilize springs, but many of them use drilled wells or combinations of springs and drilled wells, a few use dug wells, and one (Troy, Bradford County) uses an infiltration gallery in addition to a stream and a drilled well. Descriptions of the 39 public supplies using ground water at least in part and a few of those using surface water exclusively are given in the county descriptions.

QUALITY OF WATER

The general chemical character of the ground waters of north-central Pennsylvania is shown by the analytical data tabulated in the county chapters of this report and on pages 74, 75. Analyses are given of 41 samples of ground water collected in 1935 by the writer from representative wells and springs distributed as uniformly as practicable within the area and among the principal water-bearing formations. These analyses were made in the water-resources laboratory of the United States Geological Survey by E. W. Lohr.

All the analyses were made by the methods regularly used by the Geological Survey.[32] In addition, the fluoride content of several samples was determined by the method worked out by Foster.[33]

CHEMICAL CONSTITUENTS IN RELATION TO USE[34]

Total dissolved solids.—The residue from complete evaporation of a natural water consists mainly of the mineral constituents listed below, with which may be included a small quantity of organic material and a little water of crystallization. Waters with less than 500 parts per million* of dissolved solids are generally entirely satisfactory for domestic use, except for the difficulties resulting from their hardness or

[32] Collins, W. D., Notes on practical water analyses: U. S. Geol. Survey Water-Supply Paper 596, pp. 235-261, 1928.

[33] Foster, Margaret D., Colorimetric determination of fluoride in water using ferric chloride: Ind. Eng. Chem., Anal. Ed., vol. 5, pp. 234-236, 1933.

[34] Adapted in part from Collins, W. D., and Howard, C. S., Chemical character of waters of Florida: U. S. Geol. Survey Water-Supply Paper 596, pp. 181-186, 1928.

* One grain per U. S. gallon equals 17.118 parts per million.

occasional excessive iron content. The waters with more than 1,000 parts per million are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects. However, some waters that contain more than 1,000 parts per million are satisfactory for domestic use and for some industrial uses, such as cooling.

The ground waters from most springs and wells of shallow or moderate depth in north-central Pennsylvania contain less than 500 parts per million of dissolved mineral matter. Some of these waters are very low in dissolved mineral matter and may contain less than 50 parts. A few waters in the area are very high in mineral content—one sample analyzed contained 3,155 parts per million.

Ground water that percolates slowly through permeable rocks is likely to be relatively constant in mineral concentration throughout the year, but ground water that flows through solution channels in limestone or dolomite may show seasonal variations in concentration that are comparable to seasonal fluctuations in the discharge of the channels.

Silica.—Silica (SiO_2) is dissolved from practically all rocks. The silica in a water may be deposited with other scale-forming constituents in steam boilers, but otherwise it has no effect on the use of water for most purposes.

Iron.—Iron (Fe) is dissolved from many rock materials, particularly from pyrite and other iron-bearing minerals. The quantity of iron in ground water may differ materially from place to place—even in waters from the same geologic formation.

If a water contains much more than 0.1 part per million of iron, the excess may separate out after exposure to the air and settle as the reddish sediment common in many well waters in this area. Acid waters, such as are encountered in coal mines, may contain considerably more than this amount of iron in solution without forming a precipitate. Iron stains cooking utensils and bathroom fixtures and may impart a disagreeable taste if present in sufficient quantity. In certain industries iron may cause serious trouble due to staining, as in the manufacture of white paper, the tanning industry, and in laundries. Only iron-free water can be used in the repressuring of oil sands by water-flooding. Certain types of bacteria which flourish on iron may cause serious trouble by clogging water pipes and fixtures. In this area iron-bearing waters are locally called "sulphur waters," but iron and not sulphur imparts the disagreeable taste and color.

Iron is found in objectionable amounts in some of the ground waters of north-central Pennsylvania. As indicated in the table, pp. 74, 75, iron in sufficient quantity to be noticeable is reported in many wells in the area, in different water-bearing formations. One water analyzed contained 22 parts per million.

Generally iron can be easily removed from most natural waters. For domestic and many other purposes, it is generally sufficient to remove only a part of the iron, which for most waters is more easily accomplished than complete removal. For other uses, such as public water

supply, the iron must be largely removed, and for paper mills, tanneries, canneries, and other users, iron must be completely removed.

The simplest method of removing most of the iron from water is by aeration and filtration. Water may be aerated by being sprayed into the air through a series of nozzles, or by splashing over a series of steps or plates, which allows the air to come in contact with each drop of water and oxidize most of the iron. The precipitated iron can then be removed either completely or partly by one of several methods. Probably the best method is by filtration, but for some waters it is necessary to add alkalies to coagulate the fine particles into fewer but larger particles before filtration, or allow the water to settle for some time before filtration. Soft waters that contain very small quantities of dissolved solids generally require chemical treatment before iron can be removed, whereas, in many harder waters the simple methods are applicable. Some of the methods used in softening water, described below, also effectively remove iron from water. Iron is removed from ground water in many industrial and public supplies in the area, and in some of the domestic supplies.

Calcium.—Calcium (Ca) is taken into solution as the bicarbonate by the reaction of natural waters containing carbonic or organic acids with calcium carbonate, which is the principal constituent of limestone and an important constituent of dolomite. It is also dissolved in large quantities from gypsum (calcium sulphate).

Calcium is the predominant basic element in most of the ground waters of north-central Pennsylvania, and is the main cause of the hardness of these waters. Most of the ground waters analyzed contain less than 50 parts per million of calcium, although a sample from well 242, Lycoming County, contained 152 parts per million.

Magnesium.—Magnesium (Mg) is dissolved from practically all rocks but mainly from dolomite and dolomitic limestones, by reactions similar to those for calcium. In most natural waters magnesium is present in smaller amounts than calcium. Magnesium is the only element besides calcium that causes any appreciable amount of hardness in natural waters.

Sodium and potassium.—Sodium (Na) and potassium (K) are dissolved from practically all rocks. Moderate quantities of these constituents have little effect, but waters that carry more than 50 parts per million of the two may require careful operation of steam boilers to prevent foaming. Waters that contain large quantities of sodium salts injure crops, and some waters contain so much sodium that they are unfit for nearly all uses.

Most of the samples analyzed contained less than 50 parts per million of sodium; a few contained more than 100 parts. Most of the waters that contained more than 100 parts of sodium were from the Chemung formation or from formations or deposits overlying the Chemung, and probably represent diluted connate water, that is, sea water that became entrapped in the marine sediments at the time of deposition and subsequently diluted by meteoric water.

The connate waters encountered by deep oil and gas wells in the area are strong solutions of sodium chloride (common salt) with smaller quantities of other soluble salts. Some of these connate waters are much more concentrated than sea water. In the recovery of oil by the water-flooding method in McKean County, these concentrated brines are pumped out with the oil, separated from the oil in a small tank at each well, one of which is shown in plate 9B, and allowed to run into the surface streams. As the flooding practice continues, the salinity of the water pumped out becomes less owing to dilution by the fresh water pumped into the sand.[35] In some of the oil fields of the Mid-continent region, the brines pumped from oil wells have caused serious contamination of fresh ground-water supplies, and in some places have made necessary the construction of deep disposal wells or so-called evaporation ponds. In the Bradford oil field in McKean County, the contamination of fresh ground waters has not become serious as yet, but several instances of contamination have been reported.[36]

The occurrences of saline waters in water wells of moderate depth are summarized in the table on pages 74, 75, and discussed in the county chapters. Wells drilled to depths of 500 feet or more below drainage level in the Plateaus province are likely to encounter brackish or salty water, particularly within any of the synclinal basins (pl. 4) in which there is very little deep-seated circulation of ground water.

Carbonate and bicarbonate.—Carbonate (CO_3) and bicarbonate (HCO_3) in natural waters result from the solution of carbonate rocks (such as limestone, dolomite, and calcareous shale) through the action of carbonic and organic acids in the waters. Carbonate is not generally present in appreciable quantities in natural waters, but is found in some treated waters.

In most of the waters from north-central Pennsylvania that were analyzed the bicarbonate content is less than 250 parts per million. The bicarbonate as such has little effect on the use of water.

Sulphate.—Sulphate (SO_4) in ground waters is derived principally from gypsum (calcium sulphate) associated with limestone, from the oxidation of pyrite (FeS_2) and other sulphides, or from connate waters. Only two of the samples analyzed contained more than 70 parts per million of sulphate; these two samples which were calcium sulphate water, had 345 and 470 parts per million of sulphate (analyses 114 and 242).

Sulphate itself has little effect on the general use of a water. Magnesium sulphate and sodium sulphate, if present in sufficient quantity, impart a bitter taste. Sulphate in a hard water may increase the cost of softening and forms a hard scale in steam boilers that is difficult to remove. Calcium sulphate waters are likely to be encountered in the Cayuga group in this area, some of which may be too hard to be softened economically.

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[35] Torrey, Paul D., Oil field waters of the Bradford Pool: Am. Inst. Min. and Met. Eng., Tech. Pub. no. 38, 15 pp., Dec., 1927.
[36] Fettke, Charles R., Oral communication, Dec. 1937.

Chloride.—Chloride (Cl) is an important constituent of sea water and is dissolved in small quantities from rock materials or in some cases by contamination of the water with sewage. However, the sources of chloride are many and therefore its presence in large quantities cannot be taken as a definite indication of pollution. Most of the ground waters of this area that were analyzed contain less than 100 parts per million of chloride; some of the samples, however, were much higher in chloride and one contained 1,820 parts per million. In some of the brackish or salty waters reported in deep wells of the Plateaus province the chloride concentration may be very high. (See discussion of sodium and potassium above.)

Chloride has little effect on the suitability of water for ordinary use unless there is enough to impart a salty taste. Waters high in chloride may be corrosive if used in steam boilers.

Fluoride.—Fluoride (F) is dissolved from certain fluoride-bearing minerals in rocks. Drinking water that contains 1.0 part per million or more of fluoride, as it does in some parts of southwestern United States, is known to produce mottled enamel during the critical period of the formation of the second teeth.[37] Fluoride was determined in only 3 of the 41 analyses. Two of these samples contained no fluoride and one contained 0.1 part per million.

Nitrate.—Nitrate (NO_3) in water is generally considered a final oxidation product of nitrogeneous organic material. Therefore its presence in considerable quantity in ground water suggests the presence of drainage from privies, cesspools, barnyards, or other places where oxidized nitrogenous matter is common.

More than half of the samples of water from north-central Pennsylvania contain less than 1 part per million of nitrate. The nitrate content of most of the other samples was less than 6 parts per million. The samples from wells 6 and 79, in gravel, however, contained 41 and 19 parts respectively.

Hardness.—Hardness of a water is commonly recognized by the increased amount of soap needed to produce a lather, and by the curdy precipitate that forms before a permanent lather is obtained. The constituents that cause hardness are also the active agents in the formation of the greater part of all scale formed in steam boilers and in other vessels in which water is heated or evaporated.

Water with a hardness of less than 50 parts per million is generally rated as soft, and its treatment for the removal of hardness is rarely justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap, and its removal by a softening process is profitable for laundries or other industries that use large quantities of soap. Treatment for the prevention of scale is necessary for the successful operation of steam boilers using water in the upper

[37] Dean, H. T., Chronic endemic dental fluorosis: Jour. Amer. Med. Assoc., vol. 107, pp. 1269-1272, 1936.

part of this range of hardness. Hardness of more than 150 parts per million is noticed by anyone, and where the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install cisterns to collect soft rain water. Where public supplies are softened an attempt is generally made to reduce the hardness to about 100 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the additional cost.

The 41 samples of water collected in north-central Pennsylvania differed greatly in hardness; 13 had less than 50 parts per million, 3 had more than 300 parts.

There are two processes for softening water in general use, the lime and soda process and the exchange silicate or so-called "zeolite" process. Both of these methods also effectively remove excess iron.

Hydrogen sulphide.—Hydrogen sulphide is a gas which gives the characteristic odor to sulphur waters. It is commonly believed to be formed in ground waters by the reduction of sulphates.

Hydrogen sulphide in small quantities has been detected or reported in some of the ground waters in north-central Pennsylvania, particularly those from dark or black shales in the Reedsville, Hamilton, Portage, Chemung, Pottsville, and Allegheny formations, but also in some waters from the Catskill and Pocono formations and Pleistocene deposits. It usually disappears quickly when the water is allowed to stand in an open vessel. Treatment for the removal of iron will insure the removal of hydrogen sulphide from most of these waters. In some waters containing hydrogen sulphide, sulphur separates as a white precipitate, and this was reported in the waters from wells 216 and 223. In some waters containing both iron and hydrogen sulphide, a black precipitate of ferrous sulphide may form, but none of these so-called black sulphur waters were observed in this area. Aside from imparting a slight odor and taste to water, hydrogen sulphide is entirely harmless in small quantities. Hydrogen sulphide was not determined in any of the samples analyzed from this area.

SANITARY CONSIDERATIONS

It should be pointed out that the analyses of water given in the county descriptions show only the amounts of dissolved mineral matter in the water, and do not indicate the sanitary quality of the water.

Properly constructed drilled wells are generally less subject to contamination than are dug wells and springs, but great care should be exercised to protect every well and spring used for domestic or public supply from pollution. Wells should be located so as not to receive drainage from the vicinity of buildings, barns, privies, cesspools, or pastures, and should be properly sealed at the top to keep out all surface water. In the limestone valleys water in solution channels may be polluted over large areas. Some of the public water supplies from wells or springs in the area are required to chlorinate their waters, as are most of those using surface water.

Range in concentration of significant mineral constituents in waters from geologic formations of north-central Pennsylvania

[Parts per million]

Geologic formation	Number of analyses	Iron (Fe)	Chloride (Cl)	Total dissolved solids	Total hardness as $CaCO_3$	Remarks
Pleistocene lake and stream deposits:						
Samples containing less than 900 parts per million of dissolved solids (analyses 6, 79, 92, 183, 258, 297, 317, 364, 372, 448, 513)	11					Water contains considerable iron in several parts of McKean and Potter Counties, rarely elsewhere. Few occurrences of salty water where underlain by Chemung formation.
Minimum		0.1	1.6	53	45	
Maximum		14	93	467	347	
Sample containing more than 900 parts per million of dissolved solids (analysis 483)	1	6.1	465	972	270	
Allegheny and Conemaugh formations						Many Allegheny waters contain excess iron and hydrogen sulphide, some are acidic. Conemaugh not utilized in this area.
Pottsville formation: (Analyses 106, 114, 143, 433)	4					Many waters contain considerable iron. Chloride generally less than 10 parts per million. Waters have considerable range in hardness. Some waters contain hydrogen sulphide.
Minimum		.79	1.1	35	32	
Maximum		22	33	584	388	
Mauch Chunk shale						Not utilized in this area.
Pocono formation: (Analyses 101, 109, 125, 130, 342, 350, 405, 411, 438)	9					Many waters contain considerable iron. Chloride generally less than 50 parts per million, except in few deeper wells in synclines. Hardness generally less than 80 parts per million. Some waters contain hydrogen sulphide.
Minimum		1	.0	21	10	
Maximum		12	142	487	173	
Catskill and equivalent formations: (Analyses 24, 100, 162, 381, 427, 491, 547)	7					Some waters contain considerable iron. Chloride generally less than 50 parts per million, but may be greater in deep wells in synclines. Hardness generally less than 100 parts per million. Some waters contain hydrogen sulphide.
Minimum		.10	3.0	54	32	
Maximum		.31	300	648	180	

Range in concentration of significant mineral constituents in waters from geologic formations of north-central Pennsylvania—Continued

[Parts per million]

Geologic formation	Number of analyses	Iron (Fe)	Chloride (Cl)	Total dissolved solids	Total hardness as $CaCO_3$	Remarks
Chemung formation:						Many salty waters, particularly from deeper wells. Many waters contain hydrogen sulphide. Some waters contain considerable iron, and some contain natural gas. Hardness generally less than 200 parts per million.
Samples containing less than 1,000 parts per million of dissolved solids (analyses 87, 95, 266)	3					
Minimum		.11	1.1	35	22	
Maximum		.50	100	319	193	
Samples containing more than 1,000 parts per million of dissolved solids (analyses 35, 58, 488)	3					
Minimum		[1]	560	1,099	64	
Maximum		.48	1,820	3,155	275	
Onondaga, Marcellus, and Hamilton formations, Tully limestone and Portage group: (Analysis 223, Hamilton)	1	.20	10	282	249	Few waters contain much iron. Chloride content negligible. Waters generally moderately hard to hard. Some waters contain hydrogen sulphide.
Oriskany group						Unimportant in this area. In south-central Pennsylvania waters generally are very soft (see Bulletin W5).
Cayuga group and Helderberg limestone: (Analysis 242, Cayuga)	1	.16	175	1,019	544	Many limestone waters are excessively hard owing to large content of calcium sulphate. Few waters contain much iron. Chloride content generally negligible (see Bulletin W5).
Oswego, Juniata, Tuscarora, and Clinton formations: (Analysis 231, Tuscarora)	1	.40	1.0	18	15	Waters generally very soft, and contain less than 25 parts per million of dissolved solids. Water rarely contains much iron. Chloride content generally low (see Bulletin W5).
Reedsville shale						Unimportant in this area. In south-central Pennsylvania waters generally moderately hard, many waters contain hydrogen sulphide, and some contain considerable iron. Chloride content negligible (see Bulletin W5).
Ordovician limestones and dolomites						Relatively unimportant in this area. In south-central Pennsylvania hardness of waters does not exceed 200 parts per million. Chloride content negligible, iron rare (see Bulletin W5).

[1] Less than 0.1 part per million.

RELATION TO STRATIGRAPHY

The general character of the ground water in the different geologic formations or groups of formations in north-central Pennsylvania is shown by the accompanying table of the range in concentration of significant mineral constituents, which is based on 41 representative analyses, and on information reported by well owners. This table shows the minimum and maximum of each constituent without reference to any other constituent. All the minima are not necessarily derived from the same analysis; neither are all the maxima necessarily derived from a single analysis.

The above table is largely self-explanatory, but several generalizations may be made in regard to the character of the ground water, and of the occurrence of certain constituents in the different formations or groups of formations in north-central Pennsylvania and of the relation of the waters of north-central Pennsylvania to those of adjoining areas of the State described in the reports listed in figure 1.

Iron in objectionable amounts appears to be present at least locally in the waters of nearly every formation for which data are available, but is of widespread occurrence only in the Pocono, Pottsville and Allegheny formations, and in the Pleistocene deposits of certain parts of the area.

Brackish or salty water in wells of moderate depth is most commonly found in the Chemung formation. The few occurrences of slightly brackish water in the Catskill strata are probably either from wells that tap marine beds in the Catskill or that actually tap Chemung strata, or represent waters that have moved upward into the Catskill. The salty water detected or reported in some of the wells in Pleistocene deposits undoubtedly migrated from the Chemung formation. High chlorides in Pocono or Pottsville waters are generally found only in deeper wells in synclinal areas. The high chloride content of the one sample collected from the Cayuga group (no. 242) is not characteristic of waters from the Cayuga group exposed elsewhere in Pennsylvania, but is characteristic of waters from rocks of the Cayuga group (Salina) exposed in New York State and tapped by deep gas wells in Potter and Tioga Counties.

The softest well waters in the area are probably obtainable in the Oswego, Juniata, Clinton, and Tuscarora formations, and the hardest waters are most likely to be found in the Cayuga group. The hardness of the water in the other water-bearing formations appears to have a wide range.

With reference to other areas of the State, the following comparisons might be suggested: (1) The quality of water in the older rocks of north-central Pennsylvania, in and below the Portage group, appears to be very similar to that for the same series of rocks in northeastern and south-central Pennsylvania; (2), The high chloride content of many Chemung waters in north-central Pennsylvania is also characteristic of Chemung waters in northeastern and northwestern Pennsylvania, but is not characteristic of the Chemung waters of south-central Pennsylvania, which are very low in chloride; (3), The

Catskill waters of north-central Pennsylvania are somewhat comparable in quality to those of northwestern Pennsylvania, but appear to be slightly more mineralized, particularly in chloride locally, than they are in northeastern and south-central Pennsylvania; (4), The degree of hardness, total mineral content, and frequent occurrence of appreciable amounts of iron in the waters of the Pocono and Pottsville formations and locally of the Pleistocene deposits of north-central Pennsylvania is also characteristic of these waters in northwestern and southwestern Pennsylvania, but in northeastern Pennsylvania these formations yield water that is very soft, low in dissolved solids, and seldom contains appreciable amounts of iron. The Pottsville waters of south-central Pennsylvania are similar to those of north-central and western Pennsylvania, but the Pocono waters of south-central Pennsylvania are similar to those of northeastern Pennsylvania.

WATER-BEARING FORMATIONS

The areal distribution of the Paleozoic formations described below is shown on the geologic map, plate 1, and that of the glacial lake and stream deposits is shown in plate 2. Summary descriptions of the formations and their water-bearing properties are given in the generalized section, and the history of their deposition is given under Geologic History. The quality of water to be expected from the different formations is summarized in the preceding pages. Much of the geologic data, except for the Pleistocene deposits, has been taken from the published and unpublished reports listed in the bibliography; therefore, the sources of very few of these data are separately acknowledged by footnotes in the following descriptions. The formations older than the Chemung formation, comprising the Ordovician, Silurian, and lower part of the Devonian, crop out only in Lycoming County, and have not been accurately mapped and studied in this area. For more details concerning the geology and water-yielding capacity of these formations, the reader is referred to the report on south-central Pennsylvania.[38].

ORDOVICIAN SYSTEM

LOWER AND MIDDLE ORDOVICIAN SERIES

Undifferentiated limestones and dolomites*

In Nippenose and Mosquito Valleys, in southern Lycoming County, the Nittany anticline exposes a series of gray to blue limestones which probably also includes some dolomite. The exposed thickness of these rocks has not been measured, but it probably does not exceed 1,000 feet in Nippenose Valley, and may be only a few hundred feet in Mosquito Valley. The rocks exposed or near the surface probably include representatives of the Trenton limestone, Black River and Stones River groups, and possibly a little of the underlying Beekmantown group, of central Pennsylvania. They are not important as sources of ground water in this area, as most of the residents of the two valleys use small mountain springs or cisterns. They would probably yield moderate supplies of hard water to wells that encounter solution channels. Two large springs in these rocks are described under Springs, and the general occurrence of water in limestone and dolomite is discussed on pages 49-51.

UPPER ORDOVICIAN SERIES

Reedsville shale†

The Reedsville shale overlies the undifferentiated Ordovcian limestones and dolomites, and occupies the slopes of the ridges surrounding Nippenose and Mosquito Valleys, in southern Lycoming County. It consists of brown, gray, and greenish shale with some calcareous layers and some sandy layers, but is generally poorly exposed because of a covering of talus from the adjoining ridges. It is 1,000 feet thick in central Pennsylvania, but is probably about 800 feet thick in Lycoming County.

[38] Lohman, Stanley W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 5, pp. 84-103, 1938.
* "Formation II" of the Second Geological Survey of Pennsylvania.
† "Formation III" of the Second Geological Survey of Pennsylvania.

The Reedsville is unimportant as a source of water in this area, and no wells were observed on its outcrops. In south-central Pennsylvania, it generally yields small but dependable supplies of good water which locally contains hydrogen sulphide.

Oswego sandstone and Juniata formation†

The Oswego sandstone and the Juniata formation overlie the Reedsville shale. The Oswego sandstone consists of about 800 feet of hard, thick-bedded greenish-gray sandstone, with some conglomerate locally. It forms the inner and lower ridges of the double-crested ridges that surround Nippenose and Mosquito Valleys, and Fawn Ridge at the southernmost tip of Lycoming County. The Juniata formation comprises about 1,000 feet of red shale and sandstone, with a little gray sandstone. It forms the upland valleys or depressions between the inner ridges of Oswego sandstone and the outer and higher ridges of Tuscarora quartzite.

Most of the land underlain by these formations is hilly and densely forested, so that they are unimportant as sources of well water. The two formations and the talus from the Oswego give rise to numerous small springs whose waters are generally very soft and carry very little dissolved mineral matter.

SILURIAN SYSTEM

Tuscarora quartzite*

The Tuscarora quartzite overlies the Juniata formation. Owing to the extreme hardness of its inclined strata, it forms the crests of the highest ridges in southern Lycoming County, namely, Bald Eagle Mountain, North White Deer Ridge, and South White Deer Ridge. It consists almost entirely of light-gray or white quartzite, with red and green sandstone† near the top locally, and is probably about 500 feet thick. Large piles of angular boulders derived from the Tuscarora cover the ridges in many places and extend down to the valleys in some places.

Like the underlying Oswego and Juniata formations, the Tuscarora is unimportant as a source of ground water except for the small springs along its talus slopes, which generally yield very soft water low in dissolved solids. One well (no. 231) thought to tap the Tuscarora yields a small supply of very soft water (analysis 231, Lycoming Co.)

Clinton formation

The Clinton formation overlies the Tuscarora quartzite and has a long sinous outcrop through southern Lycoming County, along the north slopes of Bald Eagle Mountain and South White Deer Ridge and along the east slope of North White Deer Ridge. It is about 800 feet thick and consists mainly of green, gray, brown, and red shale and sandstone, and locally at least contains thin beds of fossiliferous

† "Oneida sandstone" and "Red Medina" respectively of the Second Geological Survey of Pennsylvania. The Juniata is classed as Silurian by the Pennsylvania Topographic and Geologic Survey.

* "Upper or white Medina" of the Second Geological Survey of Pennsylvania.

† Castanea sandstone of Frank M. Swartz.

or oolitic hematite iron ore, which characterize the Clinton formation throughout most of the Appalachian region. A bed of Clinton iron ore near Antes Fort, Lycoming County, was mined many years ago.

The Clinton is relatively unimportant as a source of ground water, as its outcrops are in most places heavily forested. It supplies small hillside springs and a few domestic wells with soft water that is low in dissolved solids. The wells, which are 30 to 138 feet deep, are reported to yield from 3 to 10 gallons a minute from shale or sandstone.

Cayuga group*

General features and subdivisions: The Cayuga group overlies the Clinton formation in Lycoming County. Its strata are largely concealed beneath the Pleistocene deposits along the south side of the Susquehanna Valley, but it crops out in a large area around the end of Bald Eagle Mountain at Muncy, and in a large area in White Deer Valley at the southeast corner of the county.

The character, subdivisions, and thickness of the Cayuga group in Lycoming County were not determined by the Second Geological Survey, but may be inferred from sections in Centre[39] and Northumberland[40] Counties. In the counties to the south the Cayuga group is divisible into 4 formations, which are in ascending order the McKenzie formation, Bloomsburg redbeds, Wills Creek shale, and Tonoloway limestone. In Centre County, the McKenzie is about 200 feet thick and is chiefly dark gray or blue limestone, but in Northumberland County it is about 156 feet thick, and consists of greenish shale with some limestone. The Bloomsburg redbeds consist mainly of red shale and sandstone with a little green shale, and range in thickness from about 50 feet in Centre County to more than 800 feet in Northumberland County. The red beds of the Bloomsburg are in evidence about two miles northwest of Muncy. The overlying Wills Creek shale consists of buff and pale-green calcareous shale and limestone and is about 350 feet thick in the nearby counties. The highest formation, the Tonoloway limestone, consists of thin-bedded dark-bluish limestone, and is the principal limestone quarried along the Susquehanna Valley in Lycoming County. It is about 400 feet thick in Centre County and about 105 feet thick in Northumberland County, in the local quarries. The Tonoloway was included and mapped with the Helderberg limestone by the Second Geological Survey.

Thus in nearby counties, the entire Cayuga group is 1,000 to 1,400 feet thick, and it is probably not less than 1,000 feet thick in Lycoming County.

In several deep test wells for gas drilled in Elk, McKean, and Potter Counties, the Cayuga group appears to be similar to that of western New York. Fettke recognizes Salina, and Cobbleskill.[41] The Salina

* Included and mapped with the Clinton formation by the Second Geological Survey of Pennsylvania.

[39] Butts, Charles, and Moore, E. S., Geology and mineral resources of the Bellefonte quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 855, pp. 53-57, 1936.

[40] Lohman, Stanley W., Ground water in northeastern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull W 4, p. 195, 1937.

[41] Fettke, C. R., Subsurface stratigraphy of northwestern Pennsylvania and a resume of gas and oil possibilities of deeper sands: Pennsylvania Topographic and Geol. Survey, Bull. 114, p. 15, 1935.

formation in New York and in the deep test wells contains rock salt, whereas the equivalent Wills Creek shale in Pennsylvania does not; therefore it is interesting to note that a sample of water from well 242 in Muncy, which probably taps the Wills Creek, contained 175 parts per million of chloride (analysis 242), which may indicate that the Wills Creek at its northernmost outcrop in Pennsylvania has some of the characteristics of the Salina.

Ground-water conditions.—In the places where the Cayuga is utilized as a source of water, lack of exposures and reliable well logs have precluded the advisability of assigning more definite geologic horizons to the wells, and in the tables they are all assigned to the Cayuga group, although most of those ending in red shale are probably in the Bloomsburg. Along much of the Susquehanna Valley it is impossible to determine whether certain wells tap the Tonoloway or the overlying Helderberg limestone.

Wells in the Cayuga obtain water from shale or limestone, but sandstone is reported to supply one well. Reported yields range from 2½ to 10 gallons a minute for domestic wells and from 25 to 160 gallons for industrial or public supply wells. Probably the largest yields are to be expected from the thicker beds of limestone, provided solution channels can be tapped. In some parts of south-central Pennsylvania large yields have been obtained from Cayugan limestones.

Wells that tap the Bloomsburg redbeds will probably obtain fairly soft water, but almost any other formation in the Cayuga, particularly the Wills Creek shale, generally yields very hard water, some of which may contain large amounts of calcium sulphate derived from gypsum or anhydrite in the rock.

DEVONIAN SYSTEM

LOWER DEVONIAN SERIES

Helderberg limestone*

General features and subdivisions.—The Helderberg limestone overlies the Tonoloway limestone, with which it was included by the Second Geological Survey of Pennsylvania, and crops out along a narrow belt through southern Lycoming County. As pointed out by Willard,[42] when the Second Geological Survey mapped Centre, Clinton, and Lycoming Counties, the Tully limestone which crops out along the north side of the Bald Eagle and Susquehanna Valleys was confused with the Helderberg limestone which crops out along the south side or middle of these valleys, and it was assumed that all or much of these valleys in some places was underlain by the Helderberg. Hence the distribution of the Helderberg shown in plate 1 is approximately correct only in the southeast corner of Lycoming County.

Swartz[43] measured and described a complete section of the Helderberg near Jersey Shore, where he found it to be 225 feet thick, and

* "Lower Helderberg limestone" of the Second Geological Survey of Pennsylvania.

[42] Willard Bradford, Portage group in Pennsylvania: Geol. Soc. America Bull., vol 46, p. 1211, Aug. 1935.

[43] Swartz, F. M., The Helderberg group from central Pennsylvania to southwestern Virginia: Pennsylvania State College, Mineral Industries Exper. Sta. Bull. 4, pp 20, 21, 1929.

divided it into three limestone members, in ascending order, the Keyser[44], Coeymans, and New Scotland. A slight hiatus exists between the New Scotland member and the overlying Oriskany group, owing to the absence from this area of the Becraft limestone. All of the members are quite fossiliferous. The Keyser limestone member is 195 feet thick and consists mainly of blue and blue-gray thin-bedded to massive limestone, with some shale and shaly limestone, coral beds, and nodular beds containing flint. The Coeymans limestone member is 18 feet thick and includes sandy, crinoidal, and shaly limestone, with some interbedded shale and black chert. The New Scotland limestone member is only 12 feet thick and is mainly dense limestone with some interbedded white chert, and contains some sandy crystalline limestone.

Ground-water conditions.—The water-yielding capacity of the Helderberg is similar to the Tonoloway and other Cayugan limestones, and it is difficult to determine which limestone supplies certain wells. The wells thought to end in the Helderberg are reported to yield from 3 to 25 gallons a minute. Larger supplies might be obtainable from wells that encounter solution channels. No analyses of Helderberg waters were made for this area, but in south-central Pennsylvania its waters are generally harder than those from Ordovician limestones, but may be softer than those from Cayugan limestones.

Oriskany group

General features and subdivisions.—The Oriskany group overlies the Helderberg limestone. The Second Geological Survey of Pennsylvania thought that the Oriskany was absent throughout most of southern Lycoming County, hence on the geologic map, plate 1, it is shown only in the southwestern and southeastern parts of the county. Recently, however, Cleaves [45] has found a complete section of the Oriskany near Montoursville, and believes that the known thicknesses of the Oriskany strongly suggest its probable occurrence in areas where it is obscured by lake and stream deposits. This is in part substantiated by the record of well 205 in Williamsport, noted below.

Throughout most of Pennsylvania and Maryland the Oriskany is divisible into two formations, the Shriver chert, limestone, or formation below, and the Ridgeley sandstone above. Cleaves found both formations present near Jersey Shore and Montoursville. He found the Shriver to be 81 feet thick near Jersey Shore and approximately 113 feet thick near Montoursville. The Shriver in this area is a thin-bedded sandy shale which weathers to a buff color.[46] He found the Ridgeley to be 65 feet thick near Montoursville and more than 93 feet thick at Jersey Shore. The Ridgeley is a gray calcareous sandstone, which weathers to a buff color. In some outcrops it is fairly well cemented with lime, or locally with silica, and in others much of the calcareous cement and color has been leached out, leaving loose, white sand.

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[44] The Keyser limestone member has been assigned to the Silurian system by Swartz, F. M., in Willard, Bradford, Devonian of Pennsylvania: (In press.)

[45] Cleaves, Arthur B., Oriskany thicknesses in Pennsylvania: Pennsylvania Acad. Sci., Proceedings, vol. XI, pp. 66, 67, 1937.

[46] Cleaves, Arthur B., personal communication, Feb. 7, 1938.

The discovery of natural gas in the deeply buried Oriskany in some of the Plateau counties of this area has created widespread interest in its possibilities in other Plateau counties. The known thicknesses and possibilities of the Oriskany are discussed in a series of reports by Cathcart and in several reports by Fettke, which are listed in the bibliography.

Ground-water conditions.—The Ridgeley sandstone is generally rather porous, especially where it is deeply weathered, and should yield water freely to wells in this area as it does in Altoona, Blair County.[47] However, as indicated above, it is largely concealed in this area, and only two wells appear to have tapped it. (Nos. 193 and 205.) Well 205 in Williamsport obtains 400 gallons a minute from the Ridgeley sandstone. The Shriver would probably yield small supplies of water, but data are not available. In south-central Pennsylvania the Oriskany generally yields moderately soft water.

MIDDLE DEVONIAN SERIES

Onondaga formaton, Marcellus shale, and Hamilton formation

General features.—In the area described in this report, the Onondaga formation, Marcellus shale, and Hamilton formation reach the surface only in Lycoming County. Along the Susquehanna Valley they are generally buried beneath lake and stream deposits, but they crop out in the southeastern part of the county. The three formations were not separately mapped by the Second Geological Survey, and together with the overlying Portage group and Chemung formation are shown by a single pattern on plate 1.

Willard[48] proposed that these three formations be grouped together under the Hamilton group, with the uppermost formation, the Hamilton, renamed the Mahantango formation, but later excluded the Onondaga.[49]

The Onondaga formation[50] is known to be present in Lycoming County from well records and observations,[51] but its thickness there has not been measured. It consists mainly of limestone and shale.

The overlying Marcellus shale consists of fissile, black shale, with local limestone concretions, and is probably several hundred feet thick.

The overlying Hamilton formation is mainly olive-green shale and sandstone, and is probably about 1,000 feet thick. The aggregate thickness of the three formations is probably 1,200-1,500 feet.

Ground-water conditions.—The only well believed to end in the Onondaga is well 204, which has a reported yield of 75 gallons a minute. The Marcellus and Hamilton yield small to moderate supplies of good water to domestic wells, and are reported to yield from 100 to 300 gallons a minute to several industrial wells in Williamsport. However, yields of more than 100 gallons a minute are probably the excep-

[47] Lohman, Stanley W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 5, pp. 146, 147, 1938.

[48] Willard, Bradford, The Onondaga formation in Pennsylvania: Jour. Geol., vol. 44, no. 5, p. 602, July-Aug., 1936.

[49] Personal communication, November 14, 1938. Willard later changed Onondaga from formation to group.

[50] "Corniferous" or "Lower Helderberg" limestone of the Second Geological Survey of Pennsylvania.

[51] Willard, Bradford, op. cit., p. 586.

tion rather than the rule. Owing to the absence of good geologic mapping and well logs, the exact geologic horizon of some of the wells reported to end in these formations is questionable.

The waters from these formations are generally moderately hard to hard. Many from the Marcellus and Hamilton contain hydrogen sulphide, and some contain objectionable amounts of iron. One sample of water was obtained from the Hamilton (analysis 223) which had a hardness of 249 parts per million.

UPPER DEVONIAN SERIES

Tully limestone and Portage group

General features and subdivisions.—The Tully limestone* and the Portage group, like the older formations, are exposed only in Lycoming County where they form the first series of hills north of the Susquehanna Valley, north and east of Hughesville, along the county boundary south of Muncy, and the hills just south of Montgomery. They are included with the Middle Devonian rocks and with the Chemung formation in plate 1, and were not separately mapped by the Second Geological Survey.

The following table shows the subdivisions of the Portage group first adopted in central Pennsylvania by Butts and those applied to the entire State by Willard.

Classification of the Portage group in Pennsylvania

Willard[52]			Butts[53]	
Portage group	Fort Littleton formation	Parkhead sandstone member		
		Trimmers rock sandstone member		
		Losh Run shale member		
		Brallier shale member	Brallier shale	Portage group
		Harrell shale member	Harrell shale gray shale member	
	Rush formation	Burkett shale member	Burkett black shale member	
		Tully limestone member	Thin limestone at top	Hamilton formation

In his study of the Portage group of Pennsylvania, Willard[54] gives two sections in southeastern and southwestern Lycoming County, from which the following descriptions are taken. The entire group ranges in thickness from about 2,500 feet at the west to about 3,000 feet at the east.

Willard's Tully member[55] is about 240 feet thick in southwestern Lycoming County, and consists mainly of hard, gray, thin-bedded limestone containing dark shale partings between the beds and numerous pyrite nodules. It is only about 80 feet thick in the southeastern part of the county.

* The Tully is included in the Portage group by Bradford Willard but according to G. A. Cooper may eventually prove to belong to the Hamilton group. Nevertheless, in Pennsylvania it is used as basal Portage.

[52] Willard, Bradford, Portage group in Pennsylvania: Geo. Soc. Am. Bull., vol. 46, p. 1199, Aug. 31, 1935.

[53] Butts, Charles, and Moore, E. S., Geology and mineral resources of the Bellefonte quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 855, pp. 64-68, 1936.

[54] op. cit., pp. 1200-1212, pl. 95.

[55] According to the classification of the Federal Survey the Tully limestone is not included in the Portage group.

His overlying Burket member[56] consists entirely of black fissile shale, and is about 100-125 feet thick. Locally, in the southeastern part of the county, it appears to be displaced by the Harrell member.

Willard's Harrell member consists of soft, brownish-gray or olive-green shale, and is 50 to 70 feet thick except where it largely displaces the Burket as noted above.

His Brallier member consists of greenish-gray shale, with some thin beds of sandstone. It is about 650 feet thick in the southwestern part of the County. In the southeastern part of the County, it is about 850 feet thick and possibly contains in its upper part Willard's Losh Run shale, which appears to be a faunal zone rather than a lithologic unit here.

His overlying Trimmers Rock member, which is regarded as the near-shore equivalent of the Brallier, is the uppermost member present in this area, and is composed of gray to greenish-gray, massive to flaggy sandstone. It is about 1,500 feet thick in southwestern Lycoming County and nearly 1,900 feet thick in the southeastern part of the county. It is very hard and forms ridges throughout the southern part of its outcrop.

Ground-water conditions.—The Portage group supplies a few wells in Lycoming County, which have reported yields of from one-half gallon to about 15 gallons a minute. Several wells near Linden and one in Williamsport tap a limestone which is probably the Tully. The "flint" reported in this limestone is probably the pyrite observed by Willard.

No analyses of Portage waters were made, but they are generally reported to be of good quality. Some of the waters are fairly hard, and a few contain hydrogen sulphide.

Chemung formation

General features.—The Chemung formation overlies the Portage group, and crops out in all of the counties covered by this report except Elk County. Its areal distribution is fairly accurately shown in plate 1, except in Lycoming County, where it is shown included with underlying Upper and Middle Devonian strata. It underlies fertile valleys in the northern counties.

The Chemung consists mainly of interbedded greenish gray and gray shales, sandy shales, and fine-grained sandstones. Thin beds of impure limestone occur locally, and in the west, brown sandstones are found. It ranges in thickness from about 1,760 feet[57] in Lycoming County, where it is fully exposed to about 2,100 feet in the Bradford oil field, where only the uppermost beds are exposed. The oil and gas sands in the Bradford field occur near the middle of the Chem-

[56] According to the classification of the Federal Survey the Burket black shale is a member of the Harrell shale.

[57] Willard, Bradford, personal communication, Feb. 2, 1938.

ung.[58] The increase in thickness of the marine Chemung formation from east to west results in part from the fact that the western area remained below sea level longer and that deposition of the overlying non-marine Catskill rocks began in the east. Over much of the area the Chemung as mapped probably includes some marine beds younger than true Chemung.

Ground-water conditions.—In Lycoming County, the Chemung like the older marine formations, has been subjected to strong folding, and whatever connate water was contained in the upturned strata has been "flushed" out by fresh meteoric ground water, with the result that these rocks now yield fresh water that is low in chloride. In the counties in the Plateaus province, however, the Chemung is the only dominantly marine formation below drainage level; and its gently folded strata have not been entirely leached of their connate water. Hence, many of the Chemung waters in the northern tier of counties are brackish or salty, and as shown on page 75, 3 of the 6 samples of water analyzed contained from 560 to 1,820 parts per million of chloride. In addition, many Chemung waters contain hydrogen sulphide, some contain considerable iron, and a few contain natural gas which can be ignited as it bubbles from the water. Many Chemung waters, however, are of fairly good quality and contain only 100 parts per million or less of chloride. In some deeper wells salt water is encountered below beds containing fresh water.

Being composed of alternate beds of sandstone and shale, the Chemung is generally a pretty good water-bearing formation. It underlies most of the valley areas in the northern counties and hence supplies more wells than any of the other rock formations. It generally yields adequate supplies for domestic use, and where sandstones are encountered it yields from 50 to as much as 200 gallons a minute to industrial and public supply wells. Locally, however, where shale is the dominant rock, it does not yield sufficient water for industrial use (see wells 49-50, Bradford County and 456, Tioga County).

CATSKILL AND EQUIVALENT FORMATIONS

General features and subdivisions.—As originally described in northern Pennsylvania by the Second Geological Survey of Pennsylvania, the Catskill was thought to overlie everywhere the marine Chemung formation, with transition beds between. Later work[59] has shown, however, that the Catskill is really a continental phase of Devonian sedimentation that began in eastern New York and northern New Jersey in Hamilton time and whose base becomes progressively younger when traced westward, until in McKean County it is probabily younger than Chemung. Moreover, the subdivisions of the non-marine Catskill in northeastern Pennsylvania, which are of Port-

[58] Fettke, Charles R., Bradford oil field (Preliminary report): Pennsylvania Topog. and Geol. Survey, Bull. 116, p. 3, May, 1937.

[59] For summary of later work, see Willard, Bradford, "Catskill," sedimentation in Pennsylvania: Geol. Soc. America Bull., vol. 44, no. 3, pp. 495-498, June, 1930.
Willard, Bradford, Continental Upper Devonian of northeastern Pennsylvania: Geol. Soc. America Bull., vol. 47, pp. 573, 574, April 30, 1936.

age, Chemung, and post-Chemung age, can be traced westward into their wholly or partly marine equivalents, as shown by recent work of Willard, part of which is shown in the following table.

Character and thickness of the subdivisions of the Catskill (modified from Willard[60]) and equivalent formations (modified from Fettke[61]) in north-central Pennsylvania

Formations in west	McKean County	Potter County	Tioga County	Bradford County	Susquehanna County	Formations in east
(Hiatus)	0	10	0–10	10	457	Mount Pleasant red shale (fresh-water)
Oswayo formation (Marine and fresh-water greenish-gray sandy shale and shaly sandstone)	198–250	325	160	140	170	Elk Mountain sandstone (fresh-water, green, cross-bedded sandstone)
Cattaraugus formation (fresh-water and marine red shales interbedded with greenish-gray shales and fine-grained greenish-gray sandstones)	300–350	350	800–1,000	800	400	Cherry Ridge red beds (fresh-water red shales, with some beds of conglomerate)
(Undifferentiated marine Chemung and some later beds)				0–100	0–200	Honesdale sandstone (fresh-water red and greenish-gray sandstone)
				0–175	125	Damascus red shale (fresh-water)
						(Undifferentiated marine Chemung and some post-Chemung including New Milford formation)

As shown in the above table, Willard's Mount Pleasant red shale is only 10 feet thick in and for some distance west of Bradford County, but is absent entirely, in and west of McKean County, where a disconformity has been recognized[62] between the Devonian and Mississippian.

Willard's Elk Mountain sandstone has been traced westward to McKean and Potter Counties where it is known as the Oswayo formation. All or most of the Oswayo was included with the overlying Pocono formation by the Second Geological Survey of Pennsylvania and is so mapped on plate 1. Conversely, in northern Potter and Tioga Counties, Fuller and Alden[63] included all the Pocono under the name Oswayo formation, and included their Oswayo and the underlying Cattaraugus formation in what they called the "Catskill-Pocono group."

[60] Willard, Bradford, idem., vol. 47, pp. 575-596, 603, April 30, 1936.
[61] Fettke, Charles R., op. cit., Bull. 116, p. 2, May, 1937.
[62] Caster, Kenneth E., The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy: Bull. Am. Paleontology, vol. 21, no. 71, p. 104, 1934.
[63] Fuller, M. L., and Alden, W. C., Description of the Elkland and Tioga quadrangles: U. S. Geol. Survey, folio 93, pp. 2, 3, 1903.
——————, Description of the Gaines quadrangle: U. S. Geol. Survey, folio 92, p. 2, 1903.

Willard's Cherry Ridge red beds grade westward into the Cattaraugus formation, attaining a maximum thickness in Tioga County. An exposure of the Cattaraugus formation, including the Salamanca sandstone member, is shown in plate 8B. The two underlying fresh-water formations grade laterally into marine strata in Susquehanna and Bradford Counties, and several still older non-marine subdivisions of northeastern Pennsylvania become wholly marine before Bradford County is reached.

In Cameron and Elk Counties, the Cattaraugus is 350 to 500 feet thick, and the overlying Devonian beds were included with the Pocono by the Second Geological Survey. In Lycoming and Sullivan Counties the undifferentiated Catskill is probably at least 2,000 feet thick.

Farther west in Warren County the rocks of equivalent age become practically wholly marine with only a few thin streaks of red shale and are known there as the Conewango formation.

The Catskill rocks generally occupy foothills or valleys.

Ground-water conditions.—As the Oswayo and Pocono formations were not mapped separately by the Second Geological Survey, wells in these formations are classified in the county well tables as ending in the Pocono (since they are very similar lithologically) except locally in the northwestern part of the area where more accurate classification was possible. The following discussion therefore pertains largely to the undifferentiated Catskill and to the Cattaraugus.

The Catskill and the Cattaraugus generally yield adequate supplies of good water for domestic needs, and yield moderately large supplies to some of the industrial and public supply wells. Some of the wells are reported to yield from 50 to 300 gallons a minute. It is similar in its water-bearing capacity to the underlying Chemung, but the Catskill waters are generally of better quality than those of the Chemung, in that they are softer and much less likely to contain appreciable amounts of sodium chloride.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

Pocono and Knapp formations

General features.—The Pocono formation in the eastern part of the area and the Knapp formation in the west overlie disconformably the Catskill rocks and their equivalents. As noted above, the Second Geological Survey of Pennsylvania generally included all or part of what is now called the Oswayo formation in the Pocono (plate 1), and some later workers have included the Pocono in the Oswayo formation. These formations are composed mainly of hard sandstones which are resistant to erosion and form the crest of the Allegheny Front and much of the high plateau surface.

In the eastern and southeastern parts of the area, the Pocono formation is entirely non-marine like the Catskill and consists mainly of gray or white sandstone with some sandy shale and conglomerate, the total thickness being about 500-600 feet.

In McKean County, the rocks of the Knapp formation are somewhat similar lithologically to the Pocono but are largely marine. In the Bradford quadrangle,[64] McKean County, the Knapp comprises a lower conglomerate, characterized by flat or discoidal pebbles some of which are composed of red jasper, overlain by shale and sandstone. The conglomerate grades laterally into sandstone resembling the underlying Oswayo. Here the Knapp is only 66-187 feet thick, the reduction in thickness being due mainly to post-Mississippian erosion described below. The Knapp is correlated by Willard[65] with a conglomerate (named by I. C. White the Griswolds Gap) at the base of the Pocono in northeastern Pennsylvania.

In the counties intervening between McKean and Sullivan Counties the thickness of the Knapp or its equivalent the Pocono, exclusive of the Oswayo, is not definitely known, but the thickness is known to increase both east and south of McKean County.

Ground-water conditions.—The rocks mapped as Pocono (now known to include the Pocono or Knapp and the underlying Oswayo) consist mainly of coarse sandstone, and where they are below drainage level, as in Elk County, and southern McKean County, they are very productive water-bearers, and are excelled only by the Pleistocene gravel and sand. Some of the wells in the Pocono yield from 300 to 600 gallons a minute. (See pp. 48, 66.)

In places where these rocks cap the plateaus, they generally yield sufficient water for domestic use, but probably would not yield large supplies owing to the drainage of the ground water from springs along the edges of the plateaus, with the attendant loss of head.

In common with waters from the overlying Carboniferous sandstones, many Pocono waters contain objectionable amounts of dissolved iron. The iron content appears to be greater in the western part of the area. Except for the iron, the Pocono waters are generally of very good quality and are quite soft.

Mauch Chunk shale

At the type locality in northeastern Pennsylvania, the Mauch Chunk shale is more than 2,000 feet thick, but it thins rapidly to the west, and in this area it is only 10 to 50 feet thick in many places, is absent entirely over wide areas, and locally in Lycoming and Tioga Counties attains a thickness of about 100 feet. During late Mauch Chunk time the area may have been completely covered by this formation, but as explained under Geologic history, the area was subjected to widespread erosion during most of the succeeding Pottsville time, so that most of the Mauch Chunk was removed and in some places all of the Mauch Chunk and part of the underlying Pocono or Knapp formations were removed. Thus when deposition was resumed in late Pottsville time, the Pottsville was laid down on the eroded remnants of the Mauch Chunk, or on the eroded surface of the Pocono or Knapp.

[64] Fettke, Charles R., op. cit., p. 2.
[65] Op. cit., p. 573.

What remains of the Mauch Chunk in this area consists mainly of red and green shale with some green and buff sandstone. It crops out only at or near the high, forested crests of the plateaus, and is not known to be utilized as a source of water in this area. It is, however, an important water-bearing formation in the anthracite region of northeastern Pennsylvania.[66]

PENNSYLVANIAN SERIES

Pottsville formation

General features and subdivisions.—As indicated above, the Pottsville formation in this area is the result of only late Pottsville deposition, and rests unconformably on the eroded Mauch Chunk, Pocono, or Knapp formations.

The Pottsville outcrops represented on plate 1 are approximately correct for most of the counties except McKean and Potter Counties. In Potter County the geologists of the Second Geological Survey mistook a conglomerate in the Pocono for the Olean conglomerate at the base of the Pottsville, and hence the Pottsville has been mapped on many hilltops now known to be underlain by the Pocono. According to Cathcart,[67] the Pottsville in Potter County is definitely known to be present only in parts of Pike, Ulysses, West Branch, Sweden, and Eulalia Townships, and may cap the highest hilltops in Abbot and Sylvania Townships. In McKean County the two upper members of the Pottsville were mapped as the overlying Allegheny formation.

The Pottsville forms the high plateau surface of most of Cameron, Elk, and McKean Counties, and of smaller isolated areas along synclinal axes in the other five counties.

Where it is more or less completely preserved from erosion, it ranges in thickness from 160 to 300 feet, but it has been partially eroded from many of the hilltops. In the western half of the area where it has received somewhat more attention it is generally divisible into five members as follows:

	Feet
Homewood (†Johnson Run*) sandstone	30–75
Mercer (Alton) shale and coal	20–35
Connoquenessing (†Kinzua Creek) sandstone	35–100
Sharon (Marshburg) shale and coal	5–15
Olean or Sharon conglomerate	50–100

The Olean conglomerate member generally consists of a white or gray conglomerate containing quartz pebbles ranging in size from ¼ inch or less up to 1 to 2 inches, but ranges laterally into a cross bedded sandstone. In contrast to the conglomerates in the Oswayo, with which is was confused by some early investigators, the pebbles in the Olean are nearly spherical instead of discoidal, and the red jasper

[66] Lohman, Stanley W., Ground water in northeastern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., pp. 49, 50, 1937.

[67] Cathcart, S. H., Gas and oil in Potter County, Pennsylvania: Pennsylvania Topographic and Geologic Survey, Bull. 106, p. 6, Feb. 1, 1934.

* Names in parentheses have been used in many of the older reports. A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the United States Geological Survey.

pebbles common to the Oswayo formation are not found in the Olean. At its type locality just north of the area the Olean is 64 feet thick and has separated along vertical joints into huge blocks of rock forming the famous "Rock City," a view of which is shown in plate 10B.

The Connoquenessing and Homewood sandstone members are generally finer grained and not so resistant to erosion as the Olean.

Some of the coals in the Mercer member have been worked locally, but those of the Sharon member are generally of little value. Pottsville coals are mined locally in Lycoming County and semi-anthracite is mined from the Pottsville in the Bernice coal basin in Sullivan County.

Ground-water conditions.—The sandstones of the Pottsville, like those of the Pocono, are very productive water-bearing formations where they lie below drainage level as they do locally in Elk and McKean Counties. Elsewhere, the Pottsville generally forms the highest capping of the plateau and yields small to moderate supplies in places sufficiently removed from the bordering escarpments.

In parts of Elk County, notably in the vicinity of St. Marys, and in southern McKean County, yields of 50 to 180 gallons a minute are reported from sandstones of the Pottsville, and it is not improbable that yields comparable to those obtained from the Pocono could be obtained locally from the Pottsville.

Many Pottsville waters contain considerable iron, one of the samples analyzed containing 22 parts per million. Some of the waters are as soft as those from the Pocono, but others are much harder. A few waters contain hydrogen sulphide. In some parts of Elk County wells are cased through the overlying Allegheny formation in search of better water in the Pottsville. In some places there is considerable range in the iron content of waters from different sandstones in the Pottsville, and if one bed yields water high in iron, it is sometimes possible to case-off the objectionable bed and encounter a water with less iron in a deeper bed.

Allegheny formation

General features.—The Allegheny formation conformably succeeds the Pottsville. It is fully preserved from erosion only in parts of southern Elk County, and in many of the other counties it has been entirely eroded away. It consists of a variable sequence of beds of sandstone, shale, limestone, clay, and coal, and contains most of the valuable coal beds of the area which are mined extensively in Elk County and also in the Blossburg coal basin of Tioga County.

In Elk County the Allegheny contains representatives of most of the coal beds of that formation that are present elsewhere in western Pennsylvania, in ascending order, the Brookville, the Clarion, the Lower, Middle, and Upper Kittanning, and the Lower and Upper Freeport. The Vanport ("Ferriferous") limestone member is found in Elk and McKean Counties and has been burned locally for agricultural lime. The Johnstown limestone member is also present in Elk County.

The thickness of the Allegheny in complete sections in southern Elk County ranges from 269 to 325 feet. About 140 feet is preserved in McKean County, 70 feet in the Blossburg basin of Tioga County, 65 feet in Cameron County, and lesser amounts in some of the other counties.

Ground-water conditions.—The sandstones in the Allegheny formation are utilized as sources of water only locally in Elk County. Where below drainage level these beds are capable of yielding considerable water. However, in areas close to active coal mines the Allegheny waters may be acid, high in iron, or the beds may be partially drained. Even where they are not affected by coal mining, the waters may contain appreciable amounts of iron, and hydrogen sulphide. For this reason some wells are cased below the lowest coal bed in the Allegheny and obtain water from the underlying Pottsville.

Conemaugh formation

The Conemaugh formation overlies conformably the Allegheny formation and is the youngest Paleozoic formation represented in the area. Only the lower member, the Mahoning sandstone, is preserved from erosion, and is found only in Jay, Benezette, Horton, and Fox Townships, Elk County. Here it is 55 to about 100 feet thick and consists of greenish-gray sandstone and shale, and massive, coarse-grained sandstone.

It is not known to be utilized as a source of water in this area, and its strata are probably largely drained owing to its topographic position capping hills.

QUARTERNARY SYSTEM

PLEISTOCENE SERIES

The interesting events of the Pleistocene epoch, which resulted in the accumulation of the most productive water-bearing beds in the area, are set forth in some detail under Geologic History. Under Ground Water, the water-bearing properties of the materials are discussed, and the quality of water in them is discussed under that subject. A brief summary of the occurrence of these deposits as water-bearing formations follows, additional details being given in the county descriptions.

Glacial drift in the uplands.—On plate 1 are shown the southern limits reached by the three stages of glaciation referable to the Jerseyan, Illinoian, and Wisconsin.

The deposits referable to the oldest or Jerseyan stage of glaciation were probably entirely removed north of the Illinoian and Wisconsin borders, and south of these borders these deposits are represented merely by scattered boulders, and hence are unimportant as sources of ground water.

In like manner, the Illinoian drift was probably entirely planed-off by the succeeding Wisconsin glacier, except in parts of Lycoming County not covered by the Wisconsin glacier. Here, mainly south of

the Allegheny Front, the hills and slopes are covered in many places by a thin veneer of reddish-clayey till.[68] In the interstream tracts and uplands, this till is nowhere known to be of sufficient thickness to be water-bearing. The Illinoian lake and stream deposits in Lycoming County are discussed under the next subheading.

The Wisconsin drift left by the last retreat of the ice covers all of Bradford County, nearly all of Sullivan and Tioga Counties, the north-eastern parts of Lycoming and Potter Counties, and a very small area at the northeast corner of McKean County. Some idea of its range in thickness in interstream areas is afforded by the figures showing depth to bedrock in plate 2, but for most of the area the thickness of the drift covering in interstream areas is not known because these areas are generally rugged and forest covered and contain few wells. As might be expected, the drift covering appears to be rather thin on the steepest slopes—areas where erosion has progressed at the most rapid rate. Hence over most of the area the reported depths to bed-rock seldom exceed 50 feet in interstream areas. In northern Bradford County, however, where the topography is more subdued, the depth to bedrock is reported to exceed 100 feet in several wells. Well 38 on a hillside near Troy penetrated 243 feet of drift, and obtained water from loose gravel, overlain by 100 feet of cemented gravel and more than 100 feet of clay and boulders. Bedrock was reported at a depth of 270 feet in a nearby well.

The depth at which bedrock might be expected cannot generally be foretold by the topography, as illustrated by several wells in Bradford County. In Sheshequin Township, wells 15 and 16 are both on the crest of a ridge and only 0.3 mile apart, yet bedrock was encountered beneath clay at a depth of 137 feet in well 16, but was struck at a depth of only 10 feet in well 15. Wells 12 and 13 in Orwell Township did not encounter bedrock at depths of 90 and 134 respectively, and obtain water from beds of glacial sand at these depths. Well 12 flows a small quantity. Well 68 in Asylum Township obtains water from stony drift at a depth of 137 feet. The glacial till generally yields but little water, but probably yields sufficient water for household use to dug wells of large storage capacity. Larger supplies are obtain-able where beds or lenses of sand and gravel are encountered, as in wells 12, 13, and 38 noted above. An exposure of stratified drift con-taining beds of sand and boulders is shown in plate 11B.

Glacial lake and stream deposits.—By far the most productive water-bearing materials in the area are the gravels and sands laid down in glacial lakes and streams. Their known areal extent and local thicknesses are shown in plate 2. It is apparent from a com-parison of plates 1 and 2 that the glacial lake and stream deposits are not restricted to the area covered by ice but rather are restricted to valleys whose streams either carried away glacial flood-waters or were dammed by the glaciers. Thus the lake and stream deposits in the northern tier of counties resulted from successive damming of north-flowing streams, some of which spilled over to the south. The

[68] Leverett, Frank, Glacial deposits outside the Wisconsin Terminal Moraine in Penn-sylvania: Pennsylvania Geol. Survey, 4th series, Bull. G 7, pp. 34-39, 1934.

only notable example of the damming of a south-flowing stream is that of the West Branch of the Susquehanna River, which was dammed near Muncy by a lobe of the Illinoian glacier.

A striking feature of most of these filled valleys is that they generally have very flat though relatively narrow bottoms, with steep-sided walls, as shown in plate 5B, yet they are filled to depths of several hundred feet in some places. Apparently the preglacial valleys were steep sided, deep, and very youthful in character before they were filled. (Probably much like the present canyon of Pine Creek, shown in plate 5C.) Thus the depths to bedrock shown on plate 2 do not necessarily indicate the maximum depths unless the well encountered bedrock in the middle of the preglacial stream channel.

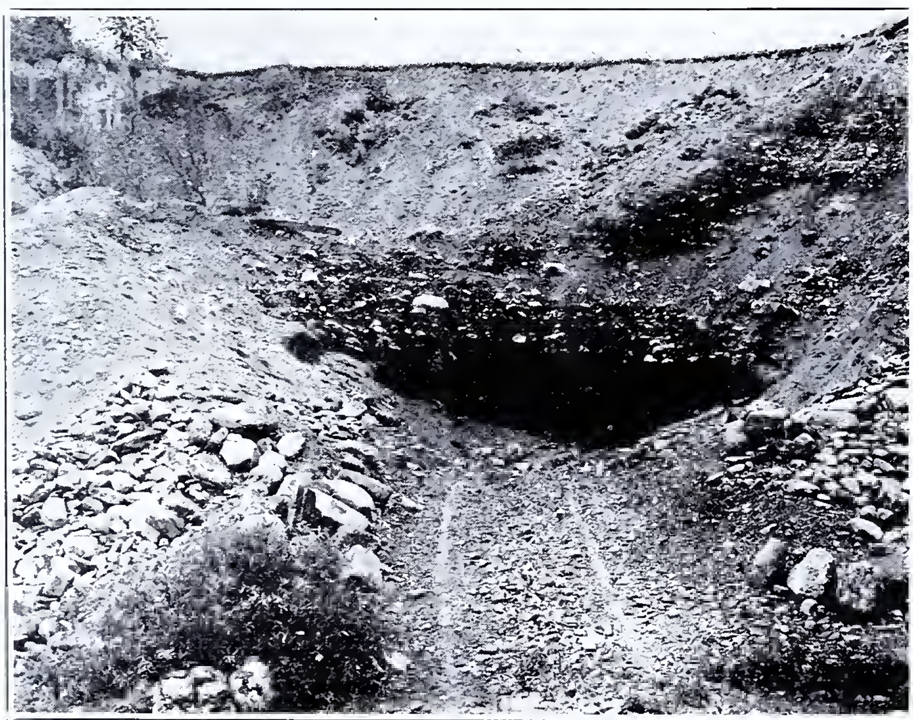
Another striking feature, particularly in McKean County, is the fact that small tributaries are filled in many places for several miles away from the main stream channel. Thus, for example, well 276 at Rixford did not encounter bedrock at a depth of 195 feet, yet it is in the comparatively narrow valley of the South Branch of Knapp Creek, more than six miles from its mouth. Numerous other examples are shown in plate 2. McKean County lies entirely south of all the glacial borders, and its valleys were filled entirely by materials carried in by the small tributaries and dumped into deep glacial lakes. The floors of the narrow tributary valleys rise gradually in altitude away from the master valleys, indicating probable gradual rise and recession of the lake waters allowing deposition to higher altitudes in tributaries than in master valleys, showing that the lakes did not persist long enough during any maximum stage to allow complete filling by sediments.

The character of the lake sediments and glacial outwash varies considerably from place to place, and may vary considerably within relatively short distances. Considerable information on the local character of these deposits is given in the remarks columns in the tables of well records and in the logs of wells, given in the county descriptions (see also fig. 10). The material is not all ideally suited for producing water, such as coarse clean sand or gravel, but at any point there may be clay, silt, sand, and gravel, either in distinct sorted beds or in various degrees of unassortment (plate 11A). By sinking a test hole all the way to bedrock, and noting carefully the character and thickness of the beds penetrated, it is, however, generally possible in most places to find beds of clean sand or gravel that will yield moderate to very large supplies to a properly constructed well. The proper method of constructing wells in such materials is discussed under Recovery, and a summary of the yields obtained in this area is given on page 47.

The character of the material, and to some extent, the quality of the water in the material, is also dependent in part upon the source of material. Glacial outwash, such as fills the valleys of Pine, Lycoming, Loyalsock, and Muncy Creeks in Lycoming County, is in part reworked glacial drift, and in part newly eroded material, and the source of the material may be both local and far-distant. This is also true of glacial lake sediments within the glaciated area. However, the

PLATE 11

A. Glacial outwash in gravel pit near Montoursville, Lycoming County.



B. Gravel pit in large mound of stratified drift near West Franklin, Bradford County.

sediments dumped into the glacial lakes in McKean County and western Potter County were necessarily entirely of local origin for reasons stated above. The principal source rocks for the coarser materials, such as boulders, gravel, and sand, were the hard, coarse sandstones and conglomerates in the Pottsville, Pocono, Knapp, and Oswayo formations. The table on page 74 shows that many waters from these formations contain considerable iron, and it is known that the iron content of such waters varies considerably from place to place. The water in the sands and gravels derived from these formations likewise is iron-bearing in some places, and the waters in certain valleys may contain considerable iron, whereas those in a nearby valley may contain very little iron. For example, the ground waters along the East Branch of Tunungwant Creek are generally iron-bearing whereas those along the West Branch are generally low in iron. The occurrence of considerable chloride locally in some of the sand or gravel waters, however, does not appear to be related to the source of the material but rather to the presence in such places of the Chemung formation beneath the unconsolidated deposits.

Non-glacial stream deposits.—The occurrence and probable mode of origin of non-glacial stream deposits in Cameron, Clinton, and southern Potter Counties, and their apparent absence from Elk County has been discussed in some detail under Geologic History. The following discussion, therefore, is limited to the character and water-yielding capacity of these deposits.

At Emporium, Cameron County, wells 95 and 96 penetrated respectively 56 and 47 feet of clay sand and gravel, but in each well the sand and gravel was reported to contain very little water, and the wells were finished in bedrock. However, a properly constructed screened well might develop an adequate supply at this locality from gravel. Well 92, near Emporium, obtains water from sand and gravel at a depth of 73 feet, the water-bearing material being overlain by 69 feet of blue clay. The water, however, is rather hard and contains considerable iron (analysis 92, Cameron County). Well 99 at Sterling Run obtains water from reddish-brown gravel at a depth of 49 feet. Water from gravel or sand could probably be obtained in other places along Sinnemahoning Creek, particularly near the mouths of tributaries, where more of the material has escaped erosion by the master streams.

In southern Potter County, the deposits appear to be thinner than those downstream. A few dug wells obtain water from these deposits along East Fork, and some drilled wells along Freemans Fork penetrate as much as 30 feet of unconsolidated material. Wells in material of this type in northern Clinton County are listed in Bulletin W 5 of this same series.

RECENT SERIES

Alluvium

Some of the streams have built up slight flood-plains during the Recent epoch, and locally such deposits may attain sufficient thickness to yield water to shallow dug or driven wells. The gravel tapped

by well 38, Elk County, may be of Recent origin as it has not been dissected by the small stream which flows over it, and may be the result of local grading of the stream. In general, Recent alluvium is probably not present in sufficient thickness to be of importance as a source of ground water.

COUNTY DESCRIPTIONS

In the pages that follow, the geography, geology, and ground-water conditions are described briefly by counties in alphabetical order, with descriptions of public and local supplies using ground water, tables of representative wells and springs, well logs, and chemical analyses of ground water.

The wells, springs, and infiltration gallery shown on plate 2 are numbered consecutively from 1 to 550 in alphabetical order by counties. In each county the wells are numbered consecutively from north to south and are tabulated by townships. The wells located in most of the boroughs are arbitrarily included in the surrounding or nearest township, but those in the cities of Bradford and Williamsport are grouped by cities. The same numbers are used to identify the logs and chemical analyses of waters.

Persons interested in the ground-water conditions of a particular locality may refer to plate 2, which shows the numbers of the nearest wells, the numbers corresponding to those in the tabulated records of wells in the county descriptions. Water analyses are also given for wells whose numbers in plate 2 are enclosed in brackets. If more information is desired, or if no nearby wells are found in plate 2, reference should be made to plates 1 and 2 to determine what geologic formation underlies the area in question. The general quantity and quality of water to be expected from the particular water-bearing formation can then be obtained by referring to the appropriate formation in the above descriptions.

BRADFORD COUNTY

[Area, 1,145 square miles. Population, 49,039]

GEOGRAPHY

Bradford County lies in the northeast corner of the area described, and is bordered on the north by New York State. The population is largely rural and averages about 43 inhabitants per square mile. Athens, Canton, Sayre, South Waverly, Towanda, and Troy are the only boroughs having 1,000 or more inhabitants. Sayre, with 7,902, is the largest borough in the county, and is followed by Athens with 4,372, and Towanda, the county seat, with 4,104. Agriculture is the principal industry, and 75 percent of the total land area of the county is devoted to farming. In 1929 Bradford County ranked third among the 67 counties of the State in annual milk production with 21,508,018 gallons. According to the Federal census of 1929, there were 66 manufacturing establishments in the county whose annual products were valued at a total of $19,803,774.

Bradford County is a deeply dissected portion of the Appalachian Plateau. The only remnants of the high plateau surface are preserved along the Blossburg and Barclay synclines in the southwestern part of the county. The highest known point in the surveyed portion of these ridges is Armenia Mountain, altitude 2,391 feet. The Susque-

hanna River leaves the county at an altitude of about 660 feet, giving a maximum known relief for the county of 1,731 feet. The local relief is about 1,000 feet in several localities, and diminishes gradually toward the eastern margin of the county.

The county is drained principally by the North Branch of the Susquehanna River, which traverses it from north to southeast. Small areas along the southern boundary of the country are drained by tributaries of the West Branch of the Susquehanna River.

GEOLOGY

The consolidated rocks exposed in Bradford County range from the Chemung formation of Upper Devonian age to the Allegheny formation of Pennsylvanian age. The Chemung formation underlies several broad anticlinal valleys which traverse the county from east to west. The Carboniferous rocks crop out only in the synclinal remnants of the high plateau. The intermediate slopes are underlain by the Catskill.

The entire county lies north of the Wisconsin glacial border (plate 1) and the bedrock is therefore covered in many places by glacial drift (see plate 11B). The range in thickness of the drift covering is discussed on previous pages and shown by well records in plate 2. The principal glacial lake and stream deposits are shown on plate 2, but lack of topographic maps and time in the field prevented detailed inspection of all the stream valleys. Thus the presence or absence of glacial outwash along Shrader Creek and some of the smaller streams is not known. Some of the interesting Tertiary and Pleistocene drainage changes in Bradford County have been described under Geologic History (see plate 6), and several glacial spillways in or near the county are shown in plate 2. That Towanda Creek was once ponded causing its waters to spill over into the south-flowing Lycoming Creek is shown by the well-developed glacial spillway at the extreme southwest corner of the county, now occupied by the Pennsylvania Railroad. A similar spillway connects the west-flowing Elk Run with a small east-flowing tributary of Wolfe Creek, just southwest of Austinville. A low pass at Snedeckerville separates the north-flowing South Creek from the south-flowing Sugar Creek, and near the mouth of Sugar Creek, just northwest of Towanda, there is a well-defined spillway cut into bedrock. Presumably Sugar Creek once flowed north, by way of South Creek, but subsequent damming of South Creek by a glacier ponded the water until it spilled over into the Susquehanna River, cutting the spillway near Towanda. After the last retreat of the glacier, that part of the creek south of Snedeckerville continued to flow in its reversed direction.

The geologic structure in Bradford County is typical of the Plateaus province. The principal folds and faults trend northeast, and are shown in plate 4.

GROUND WATER

In most parts of Bradford County rural and village water supplies are obtained largely from dug wells or springs, and along some of the valleys, from driven wells. Most of the wells used for industrial or

public supply are drilled, as are most of the newer domestic wells. The principal industrial use of ground water is for cooling in milk and ice plants, there being numerous milk plants in the county.

The glacial lake and stream deposits are unquestionably the most productive water-bearing materials in Bradford County. They have been exploited for industrial or public supplies most intensively in the boroughs of Athens, Sayre, Towanda, Canton, and Troy. Several wells ending in gravel yield more than 100 gallons a minute, the strongest of which yields 350 gallons a minute (well 46). In many places the yields of such materials could be increased considerably by the adoption of more modern methods of well construction. In the rural regions the glacial lake and stream deposits in the valleys and the glacial drift on the uplands supply numerous domestic wells. Springs 19 and 31 yield respectively about 100 and 50 gallons a minute from glacial sand and gravel, and there are numerous smaller springs that supply water from these materials.

Of the consolidated rock formations, only the Chemung and Catskill appear to be utilized as sources of ground water, since the Carboniferous rocks crop out only on the two remnants of the plateau mentioned above. These formations generally yield adequate supplies for domestic use, and in some places they yield sufficient water for certain industrial uses, although few of the industrial wells yield more than 50 gallons a minute, and only one well (no. 35 in the Chemung) was reported to yield more than 100 gallons a minute.

Records are given below of 19 flowing wells in Bradford County. A complete inventory would probably show several times this number of flowing wells, for in Troy and East Smithfield alone practically every well is reported to flow. One-third of the wells reported to flow are in glacial drift and obtain water from lenses of sand or gravel confined beneath beds of clay. The other two-thirds are in consolidated rocks, and appear to be definitely related to the geologic structure. Thus there are one or more flowing wells along each syncline in the county, and several along the flanks of anticlines. Most of the flowing wells appear to lie in the Blossburg and Windham synclines. It is probable that other flowing wells will be drilled from time to time along syncinal axes, or in favorabe drift deposits. Most of the flows are small, but wells 24, 47, and 48 were reported to flow from 25 to 50 gallons a minute.

The weekly water levels in two unused dug wells at Towanda and Monroe (nos. 52 and 70) are shown graphically in figure 5, and the possible subsurface conditions in well 52 that may allow the observed fluctuations in water level are shown in figure 7.

Analyses of 6 samples of ground water from different formations utilized as sources of supply in Bradford County are given below. Most of the ground waters in the county are satisfactory for ordinary use except some of the Chemung waters which may contain considerable sodium chloride (common salt). (Analyses 35, 58.) A few Catskill and Pleistocene waters contain noticeable amounts of chloride, but the Chemung is probably the indirect source of such waters. Some

of the Chemung waters also contain hydrogen sulphide, and a few contain natural gas which can be ignited as it separates from the water. Some of the waters in the county contain sufficient iron to produce a precipitate, but such occurrences appear to be few and scattered. Many of the waters, particularly some of those from glacial lake and stream deposits, would require softening for boiler use. The high nitrate content of the two samples from these deposits suggests contamination by surface drainage. The general quality of water to be expected from the different geologic formations is summarized on pages 74, 75, and additional notes will be found in the remarks column in the tables of well records given below.

PUBLIC WATER SUPPLIES

Athens, Canton, Sayre, South Waverly, and Wyalusing are supplied entirely by surface water. Le Raysville has the only public supply that utilizes ground water exclusively. Towanda (which also supplies Monroeton) and Troy use both ground and surface water. The remaining communities have no public supplies.

Le Raysville (population 298) is supplied entirely from one drilled well (no. 62), owned by the Le Raysville Manufacturing Company. The water is pumped directly into the mains, the excess being stored in two concrete reservoirs located on a hill in the borough. The two reservoirs hold respectively 13,500 gallons and 70,500 gallons. The service pressures range from 35 to 48 pounds per square inch. The average daily consumption is 9,000 gallons. There are 9 fire hydrants in the system. The water is chlorinated by placing chloride of lime directly in the well.

Towanda (population 4,104) and Monroe (also known as Monroeton, population 414) are supplied by the Towanda Water Works Company. The principal supply comes from Satterlee Run, a small tributary of the South Branch of Towanda Creek, in Monroe Township. The water is diverted into the main by a small concrete dam, and flows by gravity a distance of about 8 miles to the reservoirs in the borough. The stream yields about 275,000 gallons a day during normal weather, but sometimes yields much less. The second source of supply comprises the three Eilenberger Springs (no. 89), located in Albany Township, about 7 miles southeast of Satterlee Run. The aggregate yield is about 120 gallons a minute, and the water flows by gravity to join the main from Satterlee Run. The third source of supply comes from two flowing wells (nos. 47 and 48), which discharge directly into reservoir no. 2 in Towanda. The two wells together flow as much as 75 gallons a minute during the winter, but in dry weather they cease flowing. The fourth and newest source of water is from the Lehigh Valley Well (no. 46), just north of the borough, which yields 350 gallons a minute. This well discharges into the Lehigh Valley reservoir, near the well, and both the well and the reservoir are used only in emergencies. A log of this well is given below. There are three reservoirs with an aggregate capacity of 7 million gallons. The equalizing reservoir is just south of the borough at an altitude of 950 feet, and holds 1½ million gallons. Reservoir no. 2 is just west of the borough at an altitude of 990 feet, and holds 5 million gallons. Water from these two

Analyses of ground waters from Bradford County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in plate 2]

Number	6	24	35	58	79	87
Geologic horizon	Pleistocene	Catskill	Chemung	Chemung	Pleistocene	Chemung
Silica (SiO_2)	16	----	----	----	----	----
Iron (Fe)	.09	0.31	----	0.21	0.10	0.11
Calcium (Ca)	101	42	----	86	48	29
Magnesium (Mg)	23	12	----	14	7.6	3.6
Sodium (Na)	21	30	----	322	5	87
Potassium (K)	1.1					
Bicarbonate (HCO_3)	278	193	232	204	110	163
Sulphate (SO_4)	60	8	2	15	38	2
Chloride (Cl)	41	38	620	560	12	100
Nitrate (NO_3)	41	.10	.0	.50	19	.25
Total dissolved solids	467	225	[1]1,200	1,099	184	302
Total hardness as $CaCO_3$	347	154	64	272	151	87
Date of collection, 1935	Aug. 9	Aug. 14	Aug. 12	Aug. 10	Aug. 8	Aug. 8

[1] Estimated.

reservoirs is distributed by gravity at service pressures ranging from 35 to 112 pounds per square inch. The Lehigh Valley reservoir, which holds one-half million gallons, lies at an altitude of only 780 feet, hence when this supply is needed, the water is pumped into the mains by a centrifugal pump having a capacity of 450 gallons a minute. The maximum daily consumption is about 350,000 gallons. About 87 percent of the water is used for domestic purposes, and about 13 percent is used by the Lehigh Valley Railroad, the Susquehanna & New York Railroad, and several manufacturers. Only 15 percent of the service taps are metered. There are 69 fire hydrants in Towanda and 8 in Monroe. In case of fire, the pressure can be increased by 25 pounds per square inch. All sources of water are chlorinated except the two flowing wells.

Log of the Lehigh Valley well of the Towanda Water Works, north of Towanda

[No. 46. Authority, Pennsylvania Department of Health]

	Depth (feet)			Depth (feet)
Soil and boulders	0–6			
Clay and gravel	6–48	Sand, "bakey"	Well screen	61–63
Sand and dark-brown gravel	48–56	Gravel, "good"	Well screen	63–70
Clay and sand	56–60	Sand, "good"	Well screen	70–76
Fine sand and coarse gravel	60–61	Very fine sand	Well screen	76–77

Troy (population 1,190) is supplied by the Troy Borough Water Works. The principal source is infiltration gallery 29, a description of which is given on page 61. This supply, known locally as a spring, yields about 120 gallons a minute. Cases Glen Run, a small stream heading on Armenia Mountain, is impounded by a dam near the infiltration gallery holding 20,000,000 gallons, and is used when needed. There are four drilled wells just west of the borough, each of which can be pumped at a rate of 65 gallons a minute as an auxiliary supply, but owing to mutual interference only one well at a time is pumped. Near the wells is a concrete distributing reservoir holding 20,000 gallons, from which the water flows by gravity to the distributing mains. The pressures at the service taps range from 30 to 65 pounds per square inch. The average daily consumption amounts to 200,000 gallons, most of which is used for domestic purposes at a flat rate. Three manufacturers have metered taps. The water is chlorinated.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Wells Township							
1	1 mile north northwest of Mosherville	O. J. Benson	Valley	1,110	Dr	76	6	Gravel
2	Mosherville	Louis Daggett	do	1,160	DD	80	6	Gravel ?
3	1 mile northeast of Coryland Cross Roads	Albert Roy	Ridge	1,880	Dr	126	6	Blue shale
	Ridgebury Township							
4	Ridgebury	Robert Lewis	Valley		Dr	80	6	Gravel ?
	Athens Township							
5	Sayre	Sayre Brewing Co.	do		Dr	176	6	Sand and gravel
6	Athens	Pure Ice Co.	do		Dr	43.9	8	Gravel
7	do	Dairymen's League Cooperative Association, Inc.	do		Dr	40	6 or 8	do
	Windham Township							
8	Windham Center	Crowley's Milk Co., Inc.	do	960	Dr	165	8	?
	Warren Township							
9	West Warren	do	do	1,070	Dr	118	8	?
10	do	do	do	1,070	Dr	36	6	Brown sandstone
11	do	Warren Center School	Slope		Dr	100±	6	
	Orwell Township							
12	1 mile east of Orwell	J. W. Newell	Upland	1,390	Dr	90	6	Sand
13	0.9 mile southeast of North Orwell	L. B. Phillips	Hillside	1,180	DD	134	6	Black sand
14	0.3 mile north northeast of North Orwell	Crowley's Milk Co. Inc.	Valley	1,030	Dr	100	5	Calcareous shale
	Sheshequin Township							
15	0.3 mile south southeast of Black	Miles Searfoss	Upland	1,220	Dr	130	6	Gray "slate"
16	Black	Fred Kilmus	do	1,242	Dr	185	6	Gray shale

in Bradford County

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	76	—3	H	15	D	No bedrock encountered. Reported drawdown 40 feet pumping 15 gallons a minute.
do ?	80 ?	—	P	5±	D	Formerly furnished dairy with adequate supply. Water reported hard.
Chemung	16	—30	P	4	S	Reported drawndown 77 feet pumping 4¼ gallons a minute.
Pleistocene ?	?	+	F	5±	N	Flows about ¼ gallon a minute, yields about 5 gallons a minute by pumping. Formerly furnished dairy with inadequate supply. Driven well 18 feet deep yielded more water than this well.
Pleistocene	90	—31	P	27	C	Reported caved-in below 90 feet. Reported drawdown 20 feet. Water contains some hydrogen sulphide.
do	43.9	—27	S	160+	C	Pump in pit 10 feet deep. Reported very small drawdown. Considerable sand and gravel pumped out when first used causing slight cave-in. Temp. 53° F., see analysis.
do	40	—20	S	60±	C	Water reported too hard for boiler feed.
Chemung	65+(?)	—18	P	40	N	Formerly used for cooling and boiler-feed, plant shut down when visited. Reported large drawdown pumping more than 40 gallons a minute. Also have 70-foot drilled well and 20-foot dug well—both reported weak.
do	30±	+	S	40±	C, In	Flows about one gallon a minute. Reported drawdown 24 feet pumping 40 gallons a minute. Water reported satisfactory for boiler feed.
do	30	—8	S	40	In	Reported drawdown 16 feet pumping 40 gallons a minute continuously.
do	?	+3+	F	¼±	D	Flows about ¼ gallon a minute from pipe 3 feet above ground. Temp. 52° F. Water contains considerable hydrogen sulphide. There is also a drilled well at an abandoned dairy.
Pleistocene	90	+2+	F	½±	N	Flows about ½ gallon a minute from casing 2 feet above ground. Formerly supplied dairy. Water reported hard. Discharged sand when pumped heavily.
do	134	—50	P ?	5±	D	Dug 15 feet, remainder drilled. 131 feet of "hardpan" overlies black sand. Reported drawdown 50 feet after 3 hours pumping 30 gallons a minute.
Chemung	40	—6	P	20	C	Reported moderate drawdown pumping 20 gallons a minute. Water reported too hard for boiler feed.
do	10	—50	P	7	D	Reported moderate drawdown.
do	137	—22	S	5	D	137 feet of clay cased, large boulder at 30 feet. Reported drawdown 93 feet after 3 hours pumping 30 gallons a minute.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Sheshequin Township—Continued							
17	Sheshequin	Sheshequin School	Valley	740	Dr	55	6	Gravel
18	1.4 miles southeast of Milan	Mrs. Charles Mills	do		Dr	45	6	do
	Ulster Township							
19	1.5 miles south of Milan	R. D. Edmiston	do		Sp			Sand or gravel
20	Ulster	Sheffield Farms, Inc.	do	750	5 Dr	32		Gravel
21	do	do	do	750	Dr	200	8	Blue shale
	Smithfield Township							
22	East Smithfield	Burt Wilkinson	do		Dr	37	6	Gravel
23	do	East Smithfield Creamery	do		Dr	202	8	Red shale
24	do	East Smithfield Farms Co.	do		Dr	230	8	do
	Springfield Township							
25	Springfield	Miles Stone	Low ridge	1,400	Dr	130	6	Blue and red shale
	Columbia Township							
26	Columbia Cross Roads	Dairymen's League Cooperative Association, Inc.	Valley	1,140	Dr	150		Gravel
27	Sylvania	Hugh Merrit	do	1,270	Dr	50	6	do
	Armenia Township							
28	1.2 miles northwest of Alba	Mr. Thomas			Dr	2,600		Gray sandstone
	Troy Township							
29	2 miles west of Troy	Troy Borough Water Works	do	1,320	IG			Sand and fine gravel
30	0.2 mile west of Troy Borough line	do	Slope	1,260	4 Dr	170±	6	Shale

in Bradford County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	55	—35	H	5±	D	Reported small drawdown pumping 45 gallons a minute.
do	45	—23.5	S	5	D	Clay, gravel and boulders cased. First well drilled 130 feet nearby but abandoned owing to large boulder. Pump in 10-foot pit. Water level measured August 9, 1935. Reported drawdown 4 feet pumping 40 gallons a minute.
do	--------	--------	F	100±	C	Leased by Sheffield Farms, Inc. Small fluctuation reported.
do	22	—15	S	100	C	Aggregate yield of 5 wells given, reported very small drawdown. Generally only 3 wells needed. Finished with 10-foot well screens. Reported to fail in dry weather. Also have 30-foot dug well.
Chemung	99	—30	N	--------	N	50 feet of clay and gravel and underlying 49 feet of cemented gravel cased off. Pumps dry at 25 gallons a minute. Also have 330-foot abandoned well yielding only 20 gallons a minute. Water from deep well contains hydrogen sulphide.
Pleistocene	37	+	H	5±	D	Flows about one gallon a minute perennially. Many nearby wells flow or nearly flow—both from drift and bedrock.
Catskill	100±	+	P	17	C, In	About 100 feet of clay, sand and gravel cased off. Flows about 5 gallons a minute immediately after pump stops—reported to increase on standing idle. Use boiler compound. Temp. 50° F. Water level in 125-foot abandoned well reported to have been 12 feet above surface.
do	100±	+	P	85	C, In	Material cased same as above. Reported to flow about 40 gallons a minute, small drawdown pumping 85 gallons a minute. Pumping reduces flow of well 23. Temp. 50° F. Water contains hydrogen sulphide. See analysis.
do	100	—40	P	6	D	100 feet of clay and boulders cased off.
Pleistocene	150	—60±	P	--------	N	Plant closed. Reported very large drawdown pumping 18 gallons a minute.
do	50	—18	S	4	D	Reported typical of other wells in Sylvania.
Catskill or Chemung	--------	+6±	N	--------	N	Abandoned test for oil—location not checked. Salt water reported at 2,300 feet, low yield of fresh water at lesser depths.
Pleistocene	--------	—	F	140	P	See description on page 61.
Catskill	--------	—50±	P	65	P	Four similar wells—each yields 65 gallons a minute with large drawdown when only well is pumped, mutual interference if more than one is pumped.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Troy Township —Continued							
31	0.4 mile west of Troy Borough line	Pennsylvania Railroad	Valley	1,200	Sp			Sand or gravel
32	South end of Troy	Harry Kise	do	1,140	Dr	51	6	Gravel
33	do	George Lindeman	do	1,140	Dr	55	6	do
34	do	Troy Dairy Farm	do	1,150	Dr	100	6	Shale
35	Troy	Borden Co. of Pennsylvania	do	1,140	Dr	300	6	Blue shale
36	do	do	do	1,140	Dr	207	8	do
37	do	Troy Engine and Machine Co.	do	1,140	Dr	412	8	Shale ?
38	0.4 mile east north east of Troy Borough line	Glenwood Cemetery	Slope	1,120	Dr	243	6	Gravel
39	East Troy	East Troy School	Valley		Dr	70	6	do
40	1.1 miles east south east of East Troy	Leon O. Van Noy and Sons	Slope		Dr	100	6	Blue shale
	West Burlington Township							
41	1.2 miles west of West Burlington	Fordy Barnes	Valley		Dr	218	6–4	Gravel
42	West Burlington	Paul F. Essenwine	Slope		Dr	100	6	Red shale
43	1 mile west of Burlington	Bradford County Home	Hilltop		Dr	281	8	Shale
	Burlington Township							
44	Burlington	Andrew Morse	Valley		Dr	42	6	Gravel
45	0.3 mile north of Mountain Lake	Griffith Spencer	Lakeshore		Dr	106	6	Blue shale

in Bradford County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	--------	—	F	50+	R	Concrete basin and cut-off wall. Piped by gravity to watering tank near Troy station. Water reported satisfactory for locomotive boilers. Temp. 58° F.
do	51	+4	F	2±	N	Several nearby flowing wells.
do	55	+4	F, H	2±	D	Temp. 58° F.
Catskill	90±	+5±	P	20	C, In	Flows about 10 gallons a minute. Reported drawdown about 50 feet pumping 20 gallons a minute. Have another flowing well 130 feet deep not needed. 60 feet of clay cased.
Chemung	100±	+2±	N	130	N	Flows about 2 gallons a minute. Reported to have yielded 130 gallons a minute by air lift. Also have 400-foot flowing well. Temp. 52° F. Water salty and contains considerable hydrogen sulphide. Also contains natural gas which will ignite. See analysis.
do	100	+1±	N	40	N	100 feet of clay, quicksand and water-bearing gravel cased off. Reported drawdown 80 feet pumping 40 gallons a minute. Water reported fresh at 180 feet, salty below 200 feet.
do	75±	—60±	N	20±	N	Very little water reported in valley fill. Water reported fresh above 180 feet, very salty below, and natural gas bearing.
Pleistocene	243	—60	P	15	Ir	Water bearing gravel reported overlain by 100 feet of cemented gravel followed above by clay and boulders. Driller reports 270 feet of drift at nearby Oakhill cemetery.
do	70	—20	H	30	D	Clay and quicksand overlies gravel. Mostly driven wells in East Troy. One flowing well in gravel at abandoned creamery.
Chemung	25	—50±	H, P	10	S	
Pleistocene	218	—50	P	10±	S	100 feet of clay and boulders, and quicksand penetrated above gravel. Water reported cloudy.
Chemung	3	—40	P	6	D	
do	?	—90±	P	15±	D	Considerable casing used. Emergency supply, use spring ordinarily. Water reported hard.
Pleistocene	42	—12±	S	6-8	D	Similar to other wells in Burlington. Also some driven wells. 20 feet of blue clay reported above gravel.
Chemung	14	—15	P	5	D	130 feet of drift containing large boulders reported at northeast (outlet) end of lake. Most cottages have dug wells or springs.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	North Towanda Township							
46	0.1 mile north of Towanda Borough line	Towanda Water Works	Valley	750	Dr	77	10	Gravel and sand
	Towanda Township							
47	Just west of Towanda Borough line	do	Canyon	860	Dr	340	6	
48	do	do	do	860	Dr	353	10	
49	Towanda	Patterson Screen Co.	Slope	740	Dr	720	8-6	Shale
50	do	Harrington and Co.	do	740	Dr	162	6	do
51	do	do	do	740	Du	12	72±	Gravel
	Wysox Township							
52	East Towanda	C. Holon	Hillside	820	Du	64.3	30	Shale ?
53	do	Henry Van Dyne	Valley	760	Dr	70	6	Gravel
54	1 mile south southeast of East Towanda	Mr. Woodlyn	do	740	Dr	75±	6	do
55	0.9 mile west southwest of Wysox	Good Luck Inn	do	740	Dr	80	6	Gray and blue shale
56	0.8 mile west southwest of Wysox	Standard Oil Co.	do	720	Dr	140±	6	Gray shale
57	0.1 mile south of Wysox	Sheffield Farms, Inc.	do	710	Du	38	144	Gravel
58	do	do	do	710	Dr	600	6	Blue shale
59	0.1 mile northwest of Myersburg	Earl Pifer	Slope	800	DD	200	6	Gray shale
60	Myersburg	R. E. Rich	Valley	760	Dr	86	6	Gravel
	Pike Township							
61	Le Raysville	Harrington and Co.	do		Dr	200	6	Shale
62	do	LeRaysville Well Water Co.	Slope		Dr	144	6	do
63	Stevensville	Stevensville High School	Valley		Dr	138	6	Gray shale

in Bradford County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	62	—43	T	350	P	Finished with 10-inch Cook well screen 15 feet long. Reported drawdown 8 feet pumping 350 gallons a minute continuously. Reported hardness of water 196 parts per million, total solids 233 parts. See log.
Chemung	?	+	F	0–50	P	Well No. 1. Flows up to 50 gallons a minute but does not flow in some dry seasons. Water reported of good quality.
do	?	+	F	0–25	P	Well No. 2. Similar in behavior and quality of water to well 47.
do	40	—24	N	38	N	Bedrock encountered at 32 feet, 18 gallons a minute from gravel. Water level measured by owner May 25, 1934. Reported drawdown 100 feet after 12 hours pumping 38 gallons a minute. 35 gallons a minute fresh water at 288 feet, water salty below. Insufficient for needs.
do	20	—16	P	7	N	Pumped dry in 3 or 4 days at 7 gallons a minute. Water reported very hard.
Pleistocene	12	—	S ?	100	C	Reported drawdown 1½ feet.
Chemung ?	64.3	—26.4 to —57.3	N	--------	N	Observation well, equipped with float gage. Water level observed weekly since November, 1931, by H. E. Bull and later by Mrs. M. O. Parks. See figs. 5, 7.
Pleistocene	70	—30	P	6	D	
do	75±	—12	S	15	D	Location not checked.
Chemung	30	—30±	P	6	D	No water in gravel.
do	50	—2	P	30	D	50 feet sand and gravel cased, some water in gravel.
Pleistocene	38	—33±	S	180	C, In	Caisson well. 35 feet of gravel, underlain by 3 feet of clay. Boiler compound used.
Chemung	?	—50	A	50±	C	Water slightly salty and reported to contain some inflammable natural gas. Temp. 53° F. See analysis.
do	30	—28	H	2	D	Dug 30 feet, remainder drilled.
Pleistocene	86	—14	S	27	D	86 feet sand and gravel cased, clean gravel below 86. Reported drawdown 26 feet after 2 hours pumping 27 gallons a minute.
Chemung	?	—15	T	60	C, In	Reported drawdown about 10 feet pumping 60 gallons a minute continuously. Boiler compound used.
do	10	—25±	P	18	P	Reported drawdown about 15 feet abter 5 hours pumping 18 gallons a minute. Reported hardness of water 94 parts per million, total solids, 140 parts.
do	?	—	A	15	N	Water reported salty, not used. Fresh water at depth of 60–70 feet.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water
								Character of material
	Tuscarora Township							
64	0.7 mile southwest of Stevensville	Walter E. Wharburton	Hillside	------	Dr	150	6	Gray shale
65	2.5 miles northwest of Laceyville	James Graham	Steep hillside	------	Dr	194	6	Gray sandstone and shale
	Wyalusing Township							
66	Wyalusing	Dairymen's League Cooperative Association, Inc.	Valley terrace	------	Dr	150	6	------
67	1.5 miles north of Wyalusing	William Stone	Top of cliff	------	Dr	195	6	Red and gray sandy shale
	Asylum Township							
68	1.2 miles west of Durell	Orwin Braund	Hillside	------	Dr	137	6	Stony drift
	Monroe Township							
69	0.4 mile northwest of South Branch	J. R. Cowell	Valley	------	Dr	108	10	Shale
70	0.8 mile west southwest of Monroe	Mrs. Charlotte Payne	do	------	Du	5.6	36	Sandy soil
71	Powell	------	do	------	Dr	40	6	Black sand
	Franklin Township							
72	Franklindale	Franklindale Creamery, Limited	Slope	------	Dr	120	6	Hard blue shale
73	West Franklin	Joseph Burroughs	do	------	DD	100	6	Blue and gray shale
	Granville Township							
74	Granville Center	Mrs. L. D. May	Valley	------	Dr	145	6	Blue Shale
75	1 mile north of Granville Center	Emory Andrews	Hillside	------	Dr	150	6	Gravel
76	Cowley Station	Sheffield Farms, Inc.	Valley	------	Dr	159	6	Blue shale
	Canton Township							
77	Alba	do	do	------	Dr	186	6	do

in Bradford County—Continued

bearing bed						
Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung -----	4	—50	P	7	D	Reported drawdown 60 feet. 2 gallons a minute at depth of 80 feet.
do -----	22.5	—22	P	8	D	
do -----	100	—40	P	48	C, In	Boiler compound used.
Catskill -------	50	—115	P	5	D	Reported drawdown 20 or 30 feet after 10 minutes pumping 10 gallons a minute.
Pleistocene ----	137	—	P	7	D	
Catskill ? -----	?	+2+	F	10+	D	Flows about 10 gallons a minute continuously. During drought of 1930 pumped by Towanda Water Works at 82 gallons a minute continuously with less than 25 feet drawdown. Water contains hydrogen sulphide. Have another flowing well.
Recent --------	5.6	—1 to —5.6	N	--------	N	Observation well. Water level measured weekly since November, 1931, by Leon D. Pepper. See fig. 5. Large boulders prevent driving wells locally but many driven wells near Monroe.
Pleistocene ----	40	—20	H	8±	D	
Chemung -----	5	—30	P	8½	C, In	Reported drawdown about 40 feet. Several other drilled wells in Franklindale in bedrock. Many driven wells to east where gravel is thicker.
do -----	20	—25	H	6	D	Dug 20 feet, remainder drilled.
do -----	30	—7	S	10+	D, S	
Pleistocene ----	140	+	A	10+	S	Flows about ½ gallon a minute. Water in gravel lying on shale. 140 feet "hardpan" and boulders, cased. Water reported to contain iron.
Chemung -----	40	—8±	S	40	C	Reported small drawdown. 40 feet clay and gravel cased.
do -----	16	+	S	40	N	Plant closed. Flows about 5 gallons a minute. Reported drawdown less than 20 feet after 10 hours pumping 40 gallons a minute. "Hardpan" cased. Water reported to contain hydrogen sulphide.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water: Character of material
	Canton Township—Continued							
78	North part of Canton	Sheffield Farms, Inc.	Valley		Dr	201	8	Red shale
79	South part of Canton	Rosedale Dairy Co.	do		Dr	175	6	Gravel
80	do	Belmar Manufacturing Co.	do		Dr	160	6	do
81	Cedar Ledge	Dairymen's League Cooperative Association, Inc.	do		Dr	295	8	Shale
82	Grover	Sheffield Farms, Inc.	do		Dr	105	6	?
83	0.6 mile southeast of Grover	Mr. Taylor	do		Dr	70	6	Red shale
84	1 mile south southwest of Grover	Helen R. Campbell	Terrace		Dr	80±	6	do
	Leroy Township							
85	Leroy	Mr. McCraney	Valley		DD	100	6	Blue shale
	Overton Township							
86	Overton	Joseph Marshall	Slope		Dr	105	6	do
	Albany Township							
87	North part of New Albany	Dairymen's League Cooperative Association, Inc.	Valley		Dr	138	8	Shale
88	0.4 mile north of Laddsburg	Herman Eilenberger	Hillside		Dr	297	6	Red shale
89	1 mile east southeast of Laddsburg	Towanda Water Works	Valley		3 Sp			Red drift
	Terry Township							
90	1.3 miles east of New Era	Walter Newton	Ridge		Dr	160	6	White shale

[1] Dr, drilled well; Du, dug well; DD, dug and drilled well; IG, infiltration gallery; Sp, spring.

[2] A, air lift; F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated; T, turbine pump; W, windmill.

[3] C, condensing or cooling; D, domestic; In, industrial; Ir, irrigation; N, none; P, public supply; R, railroad; S, stock.

in Bradford County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung	40	—25	P	40	C, In	Red till cased. Water contains some hydrogen sulphide.
Pleistocene	175	—11	P	45	C, In	Silt, sand and gravel cased, thick gravel at bottom. Drilled in 1931 and yield has steadily increased. Abandoned shallower well pumps sand. Use boiler compound. Temp. 51° F. See analysis.
do	160	—8	S	32	In	Abandoned 136-foot well pumps sand.
Chemung	67	—60±	P	40	C	Sand, gravel, and boulders cased. Water reported hard. Have 100-foot well with same yield.
----------	?	—	P	50	C, In	
Catskill	40	—10	H	5	S	
Catskill or Chemung	10	—30	H	4±	S	
Chemung	20	+ to —1	W	6	S	Reported to flow in winter. Most wells in Leroy reported to be 60–65 feet deep.
Catskill	25	—35	P	4½	D	Reported tested at 8–10 gallons a minute. Similar to other wells in Overton.
Chemung	?	—20	P	16	C, In	Reported small drawdown. Water contains hydrogen sulphide and inflammable natural gas. Temp. 50° F. See analysis.
do	41½	—60	H	2	D	Red Soil cased.
Pleistocene	----------	—	F	120	P	Aggregate yield of 3 Eilenberger springs about 40 rods apart. Reported that yield is fairly constant, water is of good quality.
Chemung	42	—80	P	4½	D	Reported tested at 6 or 7 gallons a minute.

CAMERON COUNTY

[Area, 392 square miles. Population, 5,307]

GEOGRAPHY

Cameron County is the smallest and most thinly populated county in the area described, having only 13.5 inhabitants per square mile. Emporium, with 2,929 inhabitants, is the only borough with a population of 1,000 or more, and contains more than half the people in the county. The county is thickly forested, only 8.4 per cent of the total land area being devoted to farming, and hence is a favorite hunting region. According to the Federal census of 1929, there were 9 manufacturing establishments in the county, whose annual products were valued at a total of $6,555,333. At present the leading industry is the manufacture of radio tubes at Emporium.

The topography in Cameron County is very rugged, and comprises a high plateau standing at an altitude of about 2,000 feet, deeply dissected by Sinnemahoning Creek and its tributaries. As there are no topographic maps, the highest and lowest points and hence the relief are not known. The Three Runs Fire Tower stands on a hill 2,200 feet above sea level, which is the highest point in the small area of southernmost Cameron County that has been surveyed. Sinnemahoning Creek leaves the county at an altitude of probably about 1,000 feet, so that the relief along this stream probably exceeds 1,000 feet. The county is drained entirely by Sinnemahoning Creek, one of the principal tributaries of the West Branch of the Susquehanna River.

GEOLOGY

The consolidated rocks exposed in Cameron County range from the Chemung formation of Upper Devonian age to the Allegheny formation of Pennsylvanian age. The oldest formation, the Chemung, is exposed only in the main valleys near Emporium. The slopes of the ridges are formed by the Catskill and the plateaus are capped by the Pocono and Pottsville formations. In the central and northern parts of the county, part of the Allegheny formation is preserved on the plateau.

The geologic structure in Cameron County is typical of the Appalachian Plateaus, and comprises a series of folds trending northeast, the names and locations of which are shown in plate 4. The details of the geologic structure in relation to the possibility of finding natural gas have been described by Cathcart.[69]

GROUND WATER

Rural and village water supplies in Cameron County are obtained largely from dug or driven wells and springs, there being relatively few drilled wells in the county. Drilled wells are used by a few industries in and near Emporium to suppy water for cooling, and supply several mountain camps and some of the newer homes.

The Chemung and/or Catskill formations underlie all of the valleys and hence supply most of the drilled wells, and generaly yield enough

[69] Cathcart, S. H., The possibility of finding gas in Cameron County, Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 109, 16 pp., March 15, 1934.

water for domestic use. Only a few wells tap rock formations younger than the Catskill, since the plateau summits are only very sparsely inhabited. Pleistocene sand and gravel along the main valleys also supply a few drilled and driven wells. The maximum water-yielding capacity of these formations in this county is not known because apparently no attempts have been made to develop large supplies of ground water.

No flowing wells were reported in Cameron County. However, most of the wells for which information was obtained are located near the axes of anticlines, where the structure is unfavorable for flowing wells. It is possible that flowing wells might be obtained along some of the synclinal axes.

Analyses of ground water from 4 of the water-bearing formations utilized in Cameron County are given below. Iron was present in objectionable amounts in 2 of the samples which contained 6.5 and 12 parts per million. Aside from the high iron content of some waters, the waters of the county are generally of good quality and many are soft. The general quality of water to be expected from the different geologic formations is summarized on pages 74, 75.

Analyses of ground waters from Cameron County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in pl. 2]

Number	92	95	100	101
Geologic horizon	Pleistocene	Chemung	Catskill	Pocono
Silica (SiO_2)	—	5.9	—	—
Iron (Fe)	6.5	.27	0.19	12
Calcium (Ca)	55	5.5	25	—
Magnesium (Mg)	20	1.9	5.4	—
Sodium and potassium (Na+K)	80	Na 1.6 K .9	7	—
Bicarbonate (HCO_3)	306	18	101	41
Sulphate SO_4)	10	8.8	10	5
Chloride (Cl)	93	1.1	4.0	.0
Fluoride (F)	—	.0	—	—
Nitrate (NO_3)	.88	.10	.18	.0
Total dissolved solids	410	35	101	[1]42
Total hardness as $CaCO_3$	220	22	85	33
Date of collection, 1935	Sept. 14	Sept. 14	Sept. 14	Sept. 14

[1] Estimated.

PUBLIC WATER SUPPLIES

Emporium and Driftwood are the only boroughs in the county that have public water supplies, and each uses surface water exclusively.

Typical wells

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Shippen Township						
91	State highway 46, 2 miles southwest of McKean County line	Civilian Conservation Corps Camp S-147	Hillside		350	6	Sandstone ?
92	0.4 mile northwest of Emporium	Elmer C. Carlson	do		73	4¼	Gravel and sand
93	2 miles southwest of Emporium	John Fetter	Hill		165	6	Sandstone
94	Emporium	Warner Hotel	Valley		64	6	do
95	do	Emporium Sanitary Dairy	do		67	6	Gray sandstone
96	do	J. F. Armstrong	do		49	6	do
97	1 mile southeast of Emporium	Pennsylvania Powder Co.	do		130	6	?
	Portage Township						
98	0.7 mile south of Sizerville	James Mowrey	do		47	4¼	Red shale
	Lumber Township						
99	Sterling Run	John Charter	do		49	4¼	Reddish-brown gravel
100	0.3 mile southeast of Sterling Run	J. F. Armstrong	do		52	4	Fine sandstone
	Gibson Township						
101	About 6 miles south southeast of Driftwood	State Emergency Relief Administration, Karthaus Mountain Camp	Plateau	2,000	292	6	Sandstone

[1] H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated.
[2] C, cooling or condensing; D, domestic, In, industrial; S, stock.

in Cameron County

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[1]	Yields (gallons a minute)	Use of water[2]	Remarks
Catskill ------	23	—130	P	6	D	Water level measured October 25, 1935. Well is about 150 feet above stream.
Pleistocene ---	69	—35	P	3	D	Reported tested at 10 gallons a minute. 69 feet of blue clay cased, sand and gravel underlain by shale. Water contains considerable iron. Temp. 52° F. See analysis.
Catskill ------	20	—135	H	3±	D, S	Location not checked.
Chemung ----	33	—20	N	5±	N	Abandoned owing to high iron content of water.
do ----	56	—25	P	10	C, In	Clay, sand and gravel cased. Very little water in gravel. See analysis.
do ----	47	—10	P	10	D	Sand and gravel cased.
do ----	?	—8±	S	15	C, In	Have 3 wells 100 feet deep not used owing to hard water.
Catskill ------	39	—5	H	10	D	Iron-bearing water in greenish-gray sandstone at 28 feet cased off.
Pleistocene ---	47	—12	H	10	D	All reddish-brown gravel with some clay. Reported drawdown 15 feet after 2 hours pumping 10 gallons a minute.
Catskill ------	11	—15	S	5	D	Reported tested at 11 gallons a minute. See analysis.
Pocono ------	29	—82	P	20	D	On Hoover Road near Clearfield County line. Reported drawdown less than 10 feet after 24 hours pumping 40 gallons a minute. Temp. 48° F. Water contains considerable iron. See analysis.

ELK COUNTY

[Area, 806 square miles. Population, 33,431]

GEOGRAPHY

Elk County occupies the southwest corner of the area described in this report. The population is slightly more urban than rural, and averages 41.5 inhabitants per square mile. Fifty-five percent of the inhabitants live in the three largest boroughs; St. Marys, with 7,433; Ridgway, with 6,313; and Johnsonburg, with 4,737.

Elk County is the leading coal-producer among the counties covered by this report, and also contains several shallow oil and gas fields. The main valleys are fairly highly industrialized. According to the Federal census of 1929 there were 53 manufacturing establishments in the county whose annual products were valued at a total of $33,-477,100. Like Cameron County, Elk County is heavily forested, and only 13 percent of the total land area is devoted to farming.

The topography in Elk County is characteristic of the Appalachian high plateau. The degree and depth of dissection by streams is somewhat less than in Cameron County, and there are fairly broad remnants of the plateau which stand 1,700-2,000 feet above sea level. The highest known point in the small area of the county that has been surveyed topographically is Boone Mountain, in Horton Township, which stands about 2,370 feet above sea level. The lowest known point is where the Bennett Branch of Sinnemahoning Creek enters Cameron County, at an altitude of about 1,100 feet, giving a maximum relief of about 1,270 feet. The Clarion River leaves the county at an altitude of about 1,200 feet.

The larger part of Elk County is drained by the headwaters of the Clarion River. A small area at the northwest corner is drained by tributaries of Tionesta Creek. The area east of the continental divide, which traverses the county from northeast to south, is drained by Sinnemahoning Creek, chiefly by Bennett Branch.

GEOLOGY

The consolidated rocks exposed in Elk County range in age from the Catkill strata of Upper Devonian age (oldest) to the Conemaugh formation of Pennsylvanian age (youngest). The Catskill formation is exposed only along the bottoms of the main valleys, in Benezette Township, elsewhere the oldest formation exposed in the valleys is the Pocono. The greater part of the surface of the high plateaus is formed by the Pottsville formation, but along several synclinal basins it is formed by the Allegheny formation which contains the principal coals. The Mahoning sandstone member of the Conemaugh formation is partly preserved from erosion only in the southern tier of townships.

The geologic structure in Elk County, as in other counties of the Plateaus province, is characterized by a series of folds trending northeast, the locations and names of which are shown in plate 4. The structural details in relation to the possible occurrence of deep-seated natural gas have been described by Cathcart.[70]

[70] Cathcart, S. H., The possible occurrence of gas in the Oriskany sand of Elk County: Pennsylvania Topog. and Geol. Survey, Bull. 110, 21 pp., April, 1934.

GROUND WATER

The sandstones of the Pocono and Pottsville formations are the most productive water-bearing rocks in Elk County, and supply most of the wells. The Pocono furnishes abundant supplies of water to numerous industrial and public-supply wells located principally in communities along the Clarion River. In the vicinity of St. Marys, the Pottsville and to some extent the Allegheny formations adequately supply the industrial and public-supply wells.

Domestic water supplies on the plateau appear to be derived mainly from drilled wells, whereas along the valleys, such as that of Bennetts Branch, small hillside springs are used. Very few dug wells were observed in Elk County.

Ground water is used in considerable amount by many different industries in Elk County. The Castanea Paper Company at Johnsonburg is the largest single user of ground water in the county as well as the entire area covered by this report. This supply is also of interest in that it includes some of the strongest rock-wells in the State. A description of this interesting industrial supply is given on pp. 63-66, and the locations of the wells are shown in figures 11, 12, and 13. Considerable ground water is also used by several tanneries in Wilcox, Ridgway, and St. Marys, and by several manufacturers of carbon products at St. Marys. Ground water is used for cooling at several breweries, ice plants, and dairies in Ridgway and St. Marys. Considerable ground water is also used for public water supply, as described below.

Records were obtained of 8 flowing wells in Elk County, and in several non-flowing wells, the water was reported to stand close to the surface. All the flowing wells were reported to flow only a small quantity, generally less than one gallon a minute. One of these flowing wells (no. 138) is in Recent alluvium, the rest are in bedrock. Most of the flowing wells are near the axes of the Johnson Run, Shawmut, and St. Marys synclines, but well 144 appears to be near the axis of the Sabinsville anticline. The several synclinal basins appear to be the localities in which additional flowing wells are most likely to be obtained. The so-called "spouting wells" that have been reported near Wilcox are an entirely different phenomenon, and are described on page 46.

Analyses of 3 samples of water from the Pocono formation and 3 samples from the Pottsville formation, the two most important water-bearing formations, are given below. One sample (no. 114) contained 22 parts per million of iron and iron was reported in many wells in Elk County, including all of the wells of the Castanea Paper Company at Johnsonburg. Except for the high iron content of some waters, most of the ground waters are satisfactory for most orindary uses, but a few require softening for certain purposes. The chloride content of most of the waters is rather low, but the sample from well 130 contained 142 parts per million, one well in Johnsonburg (no. 123) encountered salty water at a depth of 230 feet. In general salt water will be encountered only locally in deep wells near synclinal axes.

PUBLIC SUPPLIES

Six communities in Elk County have public water supplies. Ridgway is supplied exclusively with surface water. Dagus Mines, Durant City, and Wilcox are supplied with ground water exclusively. Johnsonburg and St. Marys use principally surface water but have auxiliary ground water supplies. Descriptions of those supplies utilizing all or part ground water follows.

Dagus Mines, a small mining village in Fox Township, is supplied from two springs by the Northwest Mining and Exchange Company.

Analyses of ground waters from Elk County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in pl. 2]

Number	106	109	114	125	130	143
Geologic horizon	Pottsville	Pocono	Pottsville	Pocono	Pocono	Pottsville
Silica (SiO_2)	—	—	—	16	—	—
Iron (Fe)	9.2	0.54	22	.63	2.8	2.6
Calcium (Ca)	—	24	111	43	54	—
Magnesium (Mg)	—	4.1	27	8.6	9.3	—
Sodium and potassium (Na+K)	—	7	34	Na 62 K 1.9	118	—
Bicarbonate (HCO_3)	39	74	67	202	193	33
Sulphate (SO_4)	3	21	345	36	67	4
Chloride (Cl)	.4	4	33	37	142	1.1
Fluoride (F)	—	—	—	.1	—	—
Nitrate (NO_3)	.0	3.4	1.4	.16	1.7	.15
Total dissolved solids	[1]137	100	584	322	487	[1]135
Total hardness as $CaCO_3$	36	77	388	143	173	32
Date of collection, 1935	Sept. 13	Sept. 14	Sept. 13	Sept. 12	Sept. 16	Sept. 16

[1] Estimated.

The springs are located along Kersey Run, about 3 miles east of the village. The water is pumped from the springs with an electrically driven pump into a small reservoir near the source, from which a second electrically driven pump forces the water over a hill to a wooden reservoir on a hill just southwest of the village. The average consumption amounts to 57,000 gallons a day, all of which is used for domestic purposes.

Durant City (also called James City) is supplied by the Crystal Springs Park Water Company from two small springs that issue from shale in the valley of Tioncsta Creek. There are three reservoirs near the springs holding 26,180, 28,000, and 60,000 gallons, and there is a 28,000 gallon distributing tank in the village, which is on the plateau about 200 feet above the valley. The water is pumped to the distributing tank by one of two force pumps whose capacities are respectively 79 and 137 gallons a minute, whence it is distributed by gravity. The average daily consumption is 28,000 gallons, all of which is used for domestic purposes. The water is not treated.

Johnsonburg (population 4,737) is supplied by the Johnsonburg Borough Water Company principally from Silver Creek and Powers Run—two small tributaries of the Clarion River. Silver Creek sup-

plies by gravity a low-pressure system in the north and west parts of the borough, and the higher part of the borough is supplied with water pumped from a reservoir along Powers Run. The pressures in the low-pressure system range from 35 to 55 pounds per square inch, and those in the high-pressure system range from 50 to 105 pounds. The 56 fire hydrants are fed by the high pressure system. The three booster pumps are electrically driven turbines with capacities of 350 gallons a minute each. The total storage capacity is 8 million gallons, and comprises a dam that impounds 7 million gallons, and a concrete reservoir holding one million gallons. For times when stream flow is insufficient, there are 11 auxiliary drilled wells, 2 along Silver Creek and 9 along Powers Run. The 2 wells along Silver Creek (no. 110) are equipped with turbine pumps and yield 265 gallons a minute each. Two of the wells along Powers Run (nos. 124, 125) are also equipped with turbine pumps, and yield respectively 200 and 250 gallons a minute. A view of one of these wells is shown in plate 9A. The other 7 wells are pumped by air lift, with an aggregate yield of about 150 gallons a minute. About 6 weeks out of every year one of the Silver Creek wells and 4 of the Powers Run wells are pumped, the others being kept in reserve. The average daily consumption is one million gallons, of which only about 5 percent is used by railroads and manufacturers. The water from Silver Creek and the wells is chlorinated, and that from Powers Run is filtered and chlorinated. An analysis of the water from one of the wells is shown in the table (no. 125).

St. Marys (population 7,433) is supplied by the St. Marys Water Company from 4 separate plants which include 3 small streams and 30 auxiliary drilled wells. Two concrete distributing reservoirs in the borough hold respectively 2½ million and ½ million gallons. The water is distributed by gravity at pressures ranging from 25 to 110 pounds per square inch, and the water from each of the four plants described below is pumped to one or the other distributing reservoir. The average daily consumption is 800,000 gallons, of which 38 percent is used for domestic purposes, 47 percent is used for manufacturing, and 15 percent is used by the Pennsylvania Railroad and the Pittsburgh, Shawmut & Northern Railroad. There are 72 fire hydrants. All water is chlorinated at the pump stations. The wells are pumped only a short time each summer or in case of breakdown. A description of each plant follows.

The Silver Run plant is located 1 mile northwest of the borough. A dam on Silver Run impounds 2 million gallons, and there are 8 drilled wells pumped by air lift (see well 117). The water is pumped to the small distributing reservoir at the rate of 400 gallons a minute. All power is supplied by natural gas engines. A typical log of these wells follows.

Typical log of Silver Run wells of the St. Marys Water Co., northwest of St. Marys

[No. 117. Authority, Superintendent]

	Depth (feet)		Depth (feet)
Surface	0–10	Sandstone, red	95–105
Gravel	10–20	Shale, gray	105–115
Sandstone, white	20–60	Sandstone, red	115–130
Shale, gray	60–95	Shale, gray	130–150

The Young Farm plant is located 2.1 miles north of the borough and includes 6 drilled wells which are pumped directly into the mains by air lift (see wells 119). This supply is used only in emergencies. A log of a typical well follows.

Typical log of Young Farm wells of the St. Marys Water Co., north of St. Marys

[No. 119. Authority, Superintendent]

	Depth (feet)		Depth (feet)
Surface, cased	0–24	Sandstone, red	72–84
Slate	24–47	Slate	84–97
Sandstone	47–52	Sandstone	97–104
Slate	52–66	Sandstone, red, break at 166, large supply of water at 178	104–178
Sandstone (little water)	66–72	Slate	178–203

The Laurel Run plant is located 2.2 miles south of the borough, and includes a dam on Laurel Run impounding 4 million gallons, and 8 auxiliary drilled wells pumped by air lift (see well 142). Two booster pumps with capacities of 350 and 500 gallons a minute pump the water from this source to the large distributing reservoir. The log of a typical well follows.

Typical log of Laurel Run wells of St. Marys Water Co., south of St. Marys

[No. 142. Authority, Superintendent]

	Depth (feet)		Depth (feet)
Surface	0–12	Rock, red	84–87
Gravel	12–35	Shale, gray	87–112
Sandstone, white	35–70	Sandstone, "salt and pepper"	112–162
Rock, red	70–74	Sandstone, white	162–205
Shale, gray	74–84		

The Wolf Lick Run plant is 5½ miles southeast of St. Marys. A dam on Wolf Lick Run impounds 15 million gallons; and 7 drilled wells are pumped by air lift (see well 144). The water is pumped to the large distributing reservoir at the rate of 650 gallons a minute, all power being supplied by natural-gas engines.

Wilcox is supplied by the Wilcox Water Company from 6 small springs located east and southeast of the borough, and 2 auxiliary drilled wells (no. 109) located adjacent to the reservoir on a hill east of the borough. A view of the two wells and the unique pumping mechanism is shown in plate 10A. The springs and well-pumps discharge by gravity into the brick and concrete reservoir, which holds 60,000 gallons, whence the water is distributed by gravity at a maximum service pressure of 35 to 40 pounds per square inch. There are 4 fire hydrants, and in case of a severe fire, additional water can be secured from the wells of the Elk Tanning Company (no. 108) by opening a connecting valve. The average daily consumption is 10,000 gallons, all of which is used for domestic purposes. The water is not treated. An analysis (no. 109) is shown in the table. In 1934 the wells were pumped 2 or 3 hours each day during 6 dry months, but in 1935 the wells were pumped only a short time beginning September 10.

Typical wells

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Highland Township							
102	Windy City	Niagara Oil Co.	Hillside	1,840	Dr	278	6¼	Sandstone
103	0.5 mile east of Hansen	Mr. Garris	Upland	2,020	Dr	93	6	Gray shale
104	0.1 mile west of Highland Corners	Civilian Conservation Corps Camp No. 4	Ridge	2,040	Dr	226	6	Gray sandstone
105	0.7 mile south southwest of Highland Corners	T. N. Barnesdall	Hillside	1,880	Dr	150	6	Sandstone
	Jones Township							
106	0.6 mile south of Lamont	Civilian Conservation Corps Camp No. 12	Ridge	2,040	Dr	235	6	do
107	1.9 miles east southeast of Lamont	Allegheny Forest Experiment Station	Upland	2,010	Dr	150	6	White sandstone
108	Wilcox	Elk Tanning Co.	Valley	1,510	Dr	?	6	Sandstone
109	do	Wilcox Water Co.	Hillside	1,620	2 Dr	216	6	do
110	2 miles northwest of Rolfe	Johnsonburg Borough Water Co.	Canyon	1,600	2 Dr	250	8	do
111	0.6 mile east northeast of Rasselas	Catholic Church	Plateau	1,960	Dr	100	6	Gray sandstone
	Benzinger Township							
112	East end of St. Marys	St. Marys Sewer Pipe Works	Upland valley		Dr	250	6¼	White sandstone
113	St. Marys	Straub's Brewery	Plateau		Dr	150	6	do
114	do	St. Marys Beverage Co.	Upland Valley		Dr	165	6	Sandstone
115	do	Stackpole Carbon Co.	do		Dr	150±	6	do
116	Southwest end of St. Marys	Keystone Carbon Co.	Valley		Dr	108	6¼	do
117	1 mile northwest of St. Marys	St. Marys Water Co.	Upland valley		8 Dr	81–150	6	Red ? Sandstone

in Elk County

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pottsville	20	—100±	A	20	C	
Allegheny or Pottsville	22	—60	B	5	D	
Pottsville	39	—120	P	10±	D	
do	18	—110	P	2½	D	Reported tested at 15 or 20 gallons a minute.
do	42	—75	P	10	D	Reported drawdown 8 or 10 feet after 24 hours pumping 18 gallons a minute. Water contains considerable iron. Temp. 47° F. See analysis.
do	32	—65	P	14	D	Water contains excess iron.
Pocono	?	—13	S	50	In	Pump set in pit at water level. Reported drawdown less than 20 feet. Water reported to contain iron. Have another drilled well for drinking water.
do	?	—16	P	42	P	Two identical wells—each yields 42 gallons a minute. See plate 10A. Temp. 48° F. Water contains considerable iron. See analysis.
do	28	—16	T	265	P	Two identical wells—each yields 265 gallons a minute with 42 feet drawdown after 4 days pumping. Water reported to contain iron.
do	58	—60	P	2±	D	Reported tested at 20 gallons a minute. Coal and clay cased off. Water reported to contain iron.
Pottsville	140	—100±	N	32	N	Use borough water. Coal and red shale cased off owing to iron-bearing water.
do	25	—40±	T	10	C	Water reported to contain iron.
do	100	—60±	A	180±	C, In	Temp. 50° F. Upper beds cased off to eliminate some of iron-bearing water, but present supply still high in iron. See analysis.
Allegheny and Pottsville	20	—8±	T	150	In	Reported drawdown less than 20 feet after 3 hours pumping 250 gallons a minute. Water contains iron, not used for boilers.
Pocono	32	—58	P	10±	In	Plant closed when visited in September, 1935. Water reported to contain iron.
Allegheny and Pottsville	20	+ to —10	A	150	P	Silver Run wells. One well flows. Reported drawdown 21 feet pumping each well 150 gallons a minute continuously. Use only three wells at one time. Water reported to contain iron. See log of 150-foot well.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Benzinger Township —Continued							
118	1.3 miles north of St. Marys	Elk County Home	Plateau		Dr	225	8	White sandstone
119	2.1 miles north of St. Marys	St. Marys Water Co.	Upland valley		6 Dr	130–203	6	Red sandstone
120	2.3 miles northwest of St. Marys	G. G. Herrick	Plateau		Dr	105	6¼	Sandstone
	Ridgway Township							
121	Johnsonburg and up to 1 mile northeast of Johnsonburg	Castanea Paper Co.	Valley and hillside		64 Dr	154–266	8–10	do
122	Rolfe and up to 2.5 miles north northwest of Rolfe	do	do		60 Dr	150–157½	8	do
123	Johnsonburg	do	Valley		29 Dr	110–230	6–12	do
124	Southeast corner of Johnsonburg	Johnsonburg Borough Water Co.	do		Dr	250	8	do
125	do	do	do		Dr	250	8	do
126	Along Powers Run east of Johnsonburg	do	do		4 Dr	90	8	do
127	do	do	do		3 Dr	160	8	do
128	0.8 mile north of Ridgway	Hubert Schultz	Hillside		Dr	125	6	White sandstone
129	0.4 mile west of Ridgway	Benjamin Oknefski	Upland		Dr	135	6¼	do
130	Ridgway	Elk Tanning Co.	Valley		3 Dr	120	8	Sandstone
131	do	Alfred Ice Cream Co.	do		Dr	142	6	Gray sandstone
132	do	Penn Rich Ice Co.	do		Dr	120	6	Sandstone
133	0.2 mile southwest of Ridgway	John Dietz	do		Dr	85	6¼	White sandstone

Elk County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pottsville	100	—75	N	4	N	Cased-off coal streaks. Abandoned owing to small yield. Water reported hard and iron-bearing.
Allegheny and Pottsville	25	+ to —10	A	150	P	Young Farm wells. One well flows. Water reported hard and iron-bearing. See log of 203-foot well.
do	20	—50	P	8±	D	Water reported to contain iron.
Pocono	17–82	—4 to —116	A, T	60–550	In	Indian Run wells. 6 pumped with turbines, remainder air lift. See fig. 12 and p. 66. Water reported to contain iron.
do	10–45	+ to —36	A, T	75–400	In	Silver Creek wells. Two tested with turbines, remainder pumped by air-lift. See fig. 13 and p. 66. Water reported to contain iron.
do	?	—1 to —40	A, T	60–600	C, In	Mill Yard wells. 7 pumped with turbines, remainder by air lift. Deepest well yields saline water used for cooling, all waters reported to contain iron. See fig. 10 and p. 66.
do	30±	—18	T	150	P	Reported drawdown 60 feet after 24 hours pumping 150 gallons a minute. Water reported to contain iron.
do	30±	—22	T	200	P	Reported drawdown 45 feet after 24 hours pumping 200 gallons a minute. Temp. 50° F. See analysis. Shown in plate 9A.
do	28–32	+ to —12	A	75	P	Two lowest wells flow part time. Located about 100 feet apart. Water reported to contain iron. Would yield considerably more with turbine pump.
do	30±	—15±	A	75	P	Water reported to contain iron. Would yield considerably more with turbine pump.
do	20	—75	P	10	D, Ir	All water encountered at bottom. Reported tested at 100 gallons a minute.
do	32	—103	P	1	D	
do	80±	—12	S	100	In	Reported drawdown about 6 feet after 8 hours pumping each well 100 gallons a minute. Temp. 54° F. See analysis.
do	40	—20	S	100	N	Well satisfactory but not used. Pump set in pit near water level.
do ?	-------	—13	S	65	C	Pump set in 8-foot pit. Reported drawdown 10 feet pumping continuously. Water contains iron—cannot be used for making ice.
do	30	—42	P	2	D	30 feet of loam cased.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Spring Creek Township							
134	0.3 mile southwest of Portland Mills ------	Perry Dunn ---------	Hillside ---	------	Dr	118	6¼	White sandstone --
	Milestone Township							
135	2.5 miles west northwest of Hallton ----	Clement Eberly -----	Plateau ---	------	Dr	248	6¼-4	Sandstone --------
	Horton Township							
136	Shawmut -------------	Drummond Sewer Pipe Co. ----------	Valley ----	------	Dr	450	6¼	do ---- ------
137	1.6 miles northeast of Brockport -----------	Northwest Mining and Exchange Co.--	do ----	------	Dr	90	6	?
138	0.2 mile north of Brandy Camp -------	Sunnyside Inn -------	do ----	------	Dr	35	6¼	Gravel ------------
	Fox Township							
139	3.2 miles southeast of Ridgway -----------	Mrs. J. K. P. Hall--	Plateau ---	------	Dr	108	6¼	Sandstone --------
140	0.6 mile north northwest of Kylers Corners -----------------	Elvie Kyler ----------	do ---	------	Dr	116	6¼	do ---------
141	Kersey ---------------	Mathew Miller ------	do ---	------	Dr	225	6¼	Shale -------------
142	2.2 miles south of St. Marys --------------	St. Marys Water Co.	Upland valley ---	------	8 Dr	205	6	Sandstone --------
143	2.3 miles east of Kersey	Charles P. Harvey -	Plateau ---	------	Dr	112	6¼	do ---------
	Jay Township							
144	5½ miles southeast of St. Marys -----------	St. Marys Water Co.	Upland valley ---	------	7 Dr	118-285	6	Gray and white sandstone --------
145	Force ----------------	Shawmut Mining Co.	Hillside ---	------	12 Dr	80-85	6	

[1] Dr, drilled well (one unless number indicated).

[2] A, air lift; B, bucket and rope; F, natural flow; H, lift pump, hand operated; P, force pump, power operated; S, suction pump, power operated; T, turbine pump; W, windmill.

[3] C, cooling or condensing; D, domestic; In, industrial; Ir, irrigation; N, none; P, public supply; S, stock.

Elk County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pocono	32	—76	N	1	N	Slate above and below sandstone. Kept in reserve in case spring should fail. Water reported of good quality.
do	200	—180	W	1½	D, S	Water reported good. Double casing with cement between to case off iron-bearing water in coal down to 100 feet. Some water in sandstone at 150 feet.
Pottsville or Pocono	150	—100±	P	50	N	Plant closed. Iron-bearing water in coal and ferriferous limestone cased off. Some shallow flowing wells reported—all yield iron-bearing water from associated coals.
Allegheny	?	—50	P	12½	D	Water reported of good quality.
Recent	34	+	F	1±	D	Would yield more if pumped.
Allegheny	20	—68	P	1	D	Water reported of good quality. Have 150 foot well yielding iron-bearing water.
do	42	—76±	H	1½	D	Cased below one bed of coal. 75-foot well drained by coal mines.
do	140	—100	H	5	D	Cased below Lower Kittaning coal and ferriferous limestone.
Pottsville	30±	+ to —10	A	150	P	Laurel Run wells. One flows. Reported drawdown about 20 feet when each pumped at 150 gallons a minute. Water reported of good quality. See log.
do	20	—70	P	1½	D	See analysis.
Pocono	20±	+ to —10	A	100–200	P	Wolf Run wells. One flows. Reported average drawdown about 20 feet. Water reported to contain some iron. 285-foot well encountered salt water below red shale; plug set at 150 feet and now yields fresh water.
Pocono ?	?	—30±	H	5±	D	Supply cottages of mining village.

LYCOMING COUNTY

[Area, 1,220 square miles. Population, 93,421]

GEOGRAPHY

Lycoming County, the largest county in Pennsylvania, occupies the southeast corner of the area described. With 76.6 inhabitants per square mile, it is the most densely populated county in the area. However, the population is largely urban, and nearly half the inhabitants live in Williamsport, which, with 45,729 inhabitants, is by far the largest city in the area. The boroughs of Jersey Shore and South Williamsport have respectively 5,781 and 6,058 inhabitants, and the following 5 boroughs have 1,000 to 2,500 inhabitants; Duboistown, Hughesville, Montgomery, Montoursville, and Muncy. About 38 percent of the total land area is devoted to farming, chiefly land bordering the West Branch of the Susquehanna River. According to the Federal census of 1929, Lycoming County leads the 8 counties in the area in manufacturing with 180 manufacturing establishments whose annual products were valued at $78,073,506. Of the 180 establishments, 107 are in Williamsport and produced nearly 80 percent of the total output. The remaining industrial plants are chiefly along the West Branch of the Susquehanna River or its south-flowing tributaries. The manufacture of silk and rayon articles is the leading industry, and other important industries include the manufacture of gasoline motors, furniture, glue, pressed tin products, valves and fittings, wire and wire products, and the tanning of leather. A little coal is mined in the northern part of the county.

Lycoming County occupies parts of two geomorphic provinces, the Appalachian Plateaus province and the Valley and Ridge province, and hence has a more varied topography than any of the other counties of the area. The Allegheny Front, which separates the two provinces, is a striking escarpment trending east-west across the middle of the county, a view of which is shown in plate 3A. Between this escarpment and the West Branch of the Susquehanna River, are an irregular series of low, rolling hills, but south of the river are a series of high even-crested ridges and narrow valleys typical of the Valley and Ridge province. North of the escarpment the high plateau is deeply dissected by four large streams and a few small streams, one of which is shown in plate 5B.

Laurel Mountain, in Cogan House Township, stands 2,300 feet above sea level and is the highest point in that part of the area that has been surveyed topographically. Several nearby points on the plateau have altitudes of 2,200 to 2,280 feet. The West Branch of the Susquehanna River leaves the county at an altitude of about 480 feet, the lowest point in the entire area described. The maximum relief is therefore about 1,820 feet.

Lycoming County is drained almost entirely by the West Branch of the Susquehanna River, but a small area at the eastern tip of the county is drained by Fishing Creek, a tributary of the North Branch of the Susquehanna. The most important tributaries are, from west to east, Pine, Larrys, Lycoming, Loyalsock, and Muncy Creeks.

GEOLOGY

The consolidated rocks exposed in Lycoming County range in age from the undifferentiated Lower and Middle Ordovician limestones and dolomites (oldest) to the Allegheny formation of Pennsylvanian age. Lycoming County is the only county in the area in which are exposed the Ordovician, Silurian, and Lower and Middle Devonian formations, hence the descriptions of these formations given on earlier pages apply exclusively to this county. Attention has been called to the errors on plate 1 in the mapping of several Silurian and Devonian formations in Lycoming County.

As shown in plate 1, a large part of the county was covered by two and possibly three of the Pleistocene glaciers. North of the Wisconsin glacial border none of the wells in interstream tracts for which records are available, penetrated much more than 50 feet of drift, but in some parts of the county numerous swamps formerly occupied by lakes indicate greater thicknesses of Wisconsin drift. As shown in plate 2, the main valleys in the county are filled in most places to considerable depths with glacial lake and stream deposits (see plates 5B and 11A). The known depths to bedrock in these valleys range up to nearly 100 feet in many places, and at Lock Haven, Clinton County, 125 to 150 feet has been reported in wells.* Pine Creek flows over a buried valley between Waterville and its mouth, but owing to the scarcity of data it is not definitely known exactly how much farther upstream the deposits extend. Bedrock is exposed entirely across the channel near Cammal, however, and no deposits are apparent from surface indications above this point. The character of the material filling the buried valleys differs from place to place, and is composed of irregular beds or lenses of gravel, sand, silt, and clay.

The geologic structure of Lycoming County, shown in plate 4, is more complex than in any of the other counties described in this report. South of the Allegheny Front, where the structure is characteristic of the Valley and Ridge province, the beds are steeply folded and the major folds are strikingly revealed by the topography. Many of the beds dip as much as 30 or 40 degrees, and along some of the minor folds just south of the Allegheny Front the dips are nearly vertical and some of the sharp anticlines are faulted. North of the Front, the folds are relatively gentle, as in the other counties in the Plateaus province.

GROUND WATER

The glacial lake and stream deposits are unquestionably the most productive sources of ground water in Lycoming County, and supply large quantities of water to numerous industrial and public-supply wells, and also supply some domestic wells. That these deposits have not been exploited to a greater extent appears to be due mainly to a general lack of understanding on the part of the drillers of the ad-

* Lohman, S. W., Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey, 4th series, Bull. W 5, pp. 119-120, 1938.

vantages of using well screens or perforated casings rather than open finish wells. In most places these deposits contain sufficient coarse material to yield abundant supplies to wells, but in some localities the material may be too fine-grained to transmit much water. Well 212 of the Keystone Glue Company, near Newberry, affords an example of proper well construction in unconsolidated material. A log of this well follows.

Log of drilled well of the Keystone Glue Co., near Newberry

[No. 212. Authority, I. W. Kleinfelter, Superintendent]

	Depth (feet)		Depth (feet)
Red sandy clay	0–9	Sharp gray sand and gravel	31–34
Gray sand and coarse gravel	9–10	Hard sandy clay	34–50
Brown sand and large boulders	10–14	Sand and gravel (principal water-bearer)	50–55
Brown sandy clay with gravel	14–30	Blue slate	55–61
Light-brown sand	30–31		

The strongest wells in the area appear to be the 8 large dug wells of the Williamsport Water Company (no. 208), each of which is reported to yield 870 gallons a minute from sand and gravel. Other productive dug wells include nos. 194, 211, and 243.

The glacial drift in interstream areas is not an important source of ground water in this county, as it is generally quite thin.

The limestones, sandstones, and shales of Silurian and Lower and Middle Devonian age underlie most of the industrial areas and hence are exploited for large supplies at many places. They yield 50 to as much as 300 gallons a minute to some wells. The Lower and Middle Ordovician limestones are practically untried as sources of water, as most of the residents living in the two valleys underlain by these rocks are supplied from cisterns or small hillside springs. Attention is called on page 54 to two large springs that issue from these rocks.

Drilled wells and dug or caisson wells of large diameter are used to supply water for cooling, boiler feed, or processing, by many industries, including dairies, ice and ice cream manufacturers, silk mills, meat packers, furniture manufacturers, tanneries, and one glue factory. Most of the domestic supplies appear to be obtained from drilled wells and springs, but in a few localities dug wells are still in use. The use of ground water for public water supply is discussed below.

Well 216 is the only flowing well observed in Lycoming County, but in some of the other wells the water stands close to the land surface. It is entirely possible that other flowing wells may be encountered, but there appears to be no locality where such wells can be expected with any degree of certainty.

Analyses of water from five of the principal water-bearing formations in Lycoming County are tabulated below, and the general character of the water from all formations is summarized on pp. 74, 75. Except for the Cayuga group and possibly the Helderberg limestone, most of the formations in Lycoming County generally yield water that is entirely satisfactory for most purposes. Some of the waters contain objectionable amounts of iron, a few waters contain small quantities of hydrogen sulphide, and some waters may require softening for certain purposes. As shown by analysis 242, some waters from the Cayuga group are excessively hard owing to calcium sulphate. Such waters can be used for cooling and certain other purposes, but generally cannot be economically softened for boiler-feed. The presence of 175 parts per million of chloride in this sample is discussed on page 81.

Analyses of ground waters from Lycoming County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in plate 2]

Number	162	183	223	231	242
Geologic horizon	Catskill	Pleistocene	Hamilton	Tuscarora	Cayuga
Silica (SiO_2)	—	6.6	—	—	—
Iron (Fe)	.20	.01	0.20	0.40	0.16
Calcium (Ca)	—	8.6	80	—	152
Magnesium (Mg)	—	1.8	12	—	40
Sodium and potassium (Na+K)	—	Na 3.1 K .7	6	—	129
Bicarbonate (HCO_3)	36	19	220	16	105
Sulphate (SO_4)	10	10	65	2	470
Chloride (Cl)	5	4.1	10	1.0	175
Fluoride (F)	—	.0	—	—	—
Nitrate (NO_3)	1.1	5.2	.10	.45	1.6
Total dissolved solids	54	53	282	18	1,019
Total hardness as $CaCO_3$	32	29	249	15	544
Date of collection, 1935	July 29	July 25	July 29	July 27	July 25

PUBLIC SUPPLIES

Eight communities in Lycoming County have public water supplies. Jersey Shore and Montgomery are supplied exclusively by surface water. Williamsport (including South Williamsport and Duboistown) and Muncy are supplied principally with surface water but have auxiliary ground water supplies. Hughesville, Montoursville, Picture Rocks, and Ralston are supplied entirely with ground water. Descriptions are given below of the 6 public supplies that utilize ground water and of the ground water supply of the State Industrial Home for Women near Muncy.

Hughesville (population 1,868) is supplied by the Hughesville Home Water Company from two drilled wells (no. 183). There are in addition 2 drilled wells and a dug well that are not used at present. The 2 wells are pumped together by one of several triplex suction pumps,

at rates of from 250 to 400 gallons a minute. Most of the time the power for pumping is furnished by water power from Muncy Creek, which flows past the plant, but when the creek is low electric power is used. The water from the wells is chlorinated and pumped directly into the mains, the excess overflowing into a concrete reservoir which holds 500,000 gallons, located on the west slope of the valley. The service pressures range from 80 to 85 pounds per square inch. The average daily consumption is 150,000 gallons, of which about 5,000 gallons is used by a railroad and 10,000 gallons is used by manufacturers. There are 42 fire hydrants. The water is very soft, as shown by analysis 183.

Montoursville (population 2,710) is supplied by the borough from two springs and one auxiliary dug well. The two springs are located across the West Branch of the Susquehanna River in a small canyon on the north side of Bald Eagle Mountain. They issue presumably from the Clinton formation or possibly from the mantle of talus derived from the Tuscarora quartzite. Together they yield 200,000 to 300,000 gallons daily, and discharge by gravity into a nearby 500,000 gallon reservoir whence the water is distributed by gravity at an average pressure of about 65 pounds per square inch. Additional water when needed is obtained from the dug well (no. 194) which is pumped at the rate of 350 gallons a minute directly into the mains by an electrically driven suction pump. The average daily consumption is about 250,000 gallons, all of which is used for domestic purposes. There are 67 fire hydrants. The water from the well is chlorinated, but the spring water is not treated.

Muncy (population 2,413) is supplied by the Muncy Water Supply Company. The principal source is Glade Run, a small stream southeast of the borough, from which water flows by gravity into a 2-million gallon brick reservoir and is distributed by gravity. There is also an auxiliary ground water supply comprising a large dug well (no. 243) just southeast of the borough, and 4 drilled wells (no. 240) just north of the borough. The water from the dug well is pumped directly into the mains at the rate of 400 gallons a minute with a centrifugal pump driven by a Diesel engine. The four drilled wells are pumped by air lift at an aggregate rate of 160 gallons a minute, the air being supplied by a 10-horsepower electrically-driven air compressor. Owing to mutual interference resulting from too close spacing of the wells, it is said that one well alone will yield about as much as all four wells pumped together. The wells discharge into a 7,200-gallon concrete receiving basin, whence the water is pumped into the mains by an

electrically driven centrifugal pump at the rate of 350 gallons a minute. A log of one of these wells follows.

Log of well No. 1 of the Muncy Water Supply Company at Muncy

[No. 240. Authority, Pennsylvania Department of Health]

	Depth (feet)		Depth (feet)
Loam	0–3	Hardpan	31–34
Gravel	3–31	Red shale	34–140

In cases of emergency, water can be pumped directly into the mains from the West Branch of the Susquehanna River. The service pressures range from 45 to 75 pounds per square inch. The average daily consumption is about 350,000 gallons, 15 percent of which is used by manufacturers. There are 47 fire hydrants. All sources of water are chlorinated except the drilled wells.

The State Industrial Home for Women in Clinton Township, across the river from Muncy, is supplied entirely with ground water. The main supply comes from a spring on the slope of Bald Eagle Mountain, which issues from sandstone of the Clinton formation. The spring discharges into a nearby 500,000 gallon reservoir, whence the water is distributed by gravity at a pressure of 65 pounds per square inch. When the spring is low, an auxiliary supply is obtainable from 2 drilled wells (nos. 238 and 239) that yield respectively 75 and 100 gallons a minute from gravel. The water is pumped directly into the mains by the turbines in the wells. The average daily consumption is 50,000 gallons. The water is not treated.

Picture Rocks (population 548) is supplied by the Picture Rocks Spring Water Company from 2 springs and one drilled well (no. 177). The main supply comes from 2 springs, which issue at or near the contact between the Chemung and Catskill formations, on the slopes of the hill north of the borough. The 2 springs together yield about 10,000 gallons a day, and discharge into a nearby 31,000 gallon masonry reservoir, whence the water is distributed by gravity at a maximum pressure of about 75 pounds per square inch. When the well is needed, it is pumped at the rate of 50 gallons a minute into a 950-gallon pneumatic tank which is connected directly to the mains. The average daily consumption is 10,000 gallons, most of which is used for domestic purposes. The water is not treated. The hardness of the spring water is reported to be only 18 parts per million, and that of the well water is reported to be 160 parts. Three factories in the borough are supplied by large dug wells, such as well 181.

Ralston is supplied by the Ralston Water Company from 2 springs and one drilled well (no. 153). The springs are located on a steep hillside just above the 108,000 gallon concrete reservoir. When needed, well 153 is pumped at a rate of 15 gallons a minute, and discharges into the reservoir. The water is distributed by gravity at pressures ranging from 46 to 56 pounds per square inch. The average daily consumption is 4,000 gallons, all of which is used for domestic purposes. There are 4 fire hydrants. The water is chlorinated as it leaves the reservoir. It was reported that in 1932 the drilled well was used from July 1 to September 10.

Williamsport (population 45,729), South Williamsport (population 6,058), and Duboistown (population 1,049) are supplied by the Williamsport Water Company, a subsidiary of the Community Water Service. The main supply comes by gravity from Hagerman Run and Mosquito Creek, two small streams that cut through Bald Eagle Mountain south of the city. The total storage capacity is 32,100,000 gallons, comprising a 21-million gallon open-earth reservoir on Mosquito Creek, a similar 6.6 million gallon reservoir on Hagerman Run, a 4-million gallon concrete balancing reservoir on the north side of the city, and a 500,000-gallon concrete reservoir on the north side to serve the higher parts of the city. The latter reservoir is filled by two centrifugal booster pumps whose combined rate is 1,000 gallons a minute. The water is distributed by gravity at pressures ranging from 30 to 65 pounds per square inch. The pressures at the 538 fire hydrants, however, range from 55 to 120 pounds per square inch. When the stream supply is inadequate, an auxiliary supply is obtained from 8 large dug wells (no. 208) located on the Municipal Golf Course in the city. The wells, which end in gravel, are pumped as a unit directly into the mains by one or more of 4 large steam-driven suction pumps at a maximum aggregate rate of 7,000 gallons a minute, which averages 870 gallons a minute for each well. These are the strongest wells reported in the area. The average daily consumption ranges from 5 to 6 million gallons, part of which is used by several railroads and numerous manufacturers. All water is chlorinated. The two streams generally supply all needs except for parts of July, August, and September, but during the summer of 1931, when the streams were practically dry as a result of a drought, the wells furnished practically the entire supply of more than 5 million gallons daily, which is only about half of the potential ground water supply available. The following table shows the percent of the total supply furnished by each of the three sources for 1929 to 1934 inclusive.

Quantity of water supplied by Williamsport Water Company, 1929 to 1934, inclusive, in percentage from each source.

Year	1929	1930	1931	1932	1933	1934
Mosquito Creek	63	57	41	67	79.2	65
Hagerman Run	21	14	12	18	20.7	25
8 dug wells (No. 208)	16	29	47	15	.1	10

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Brown Township							
146	Slate Run	C. I. Campbell	Slope	750±	Dr	55	6	Gray shale
	McHenry Township							
147	2 miles west southwest of Trout Run Station	Edwin Summerson	Ridge		Dr	178	6	Sandstone
	Pine Township							
148	1.4 miles west southwest of Oregon Hill	Homer Teed	Hilltop		Dr	150	6	
149	0.5 mile east of Oregon Hill	John Teed	Slope		Dr	60	6	
150	English Center	Willard English	Valley	880	Dr	35	6	Gravel
151	do	Mrs. Grasso	do	880	Dr	85	?	Sandstone
	Jackson Township							
152	Buttonwood	D. W. Day	do	1,300	Dr	30	6	Sand or gravel
	McIntyre Township							
153	Ralston	Ralston Water Co.	do	888.5[4]	Dr	95	5	Gray sandstone
	McNett Township							
154	Roaring Branch	Sheffield Farms, Inc.	do		Dr	75	6	
	Plunketts Creek Township							
155	0.3 mile southwest of Barbours	T. R. Adams	do	720	Dr	40	6	Gravel
156	3.2 miles west southwest of Barbours	Mrs. Ada Faries	do	680	Dr	75	6	do
157	4.2 miles southwest of Barbours	Arthur Wolliver	do	680	Dr	48	6	do
	Gamble Township							
158	1.7 miles north northwest of Loyalsock	Oliver Nearily	do	600	Dr	52	6	do
159	do	Robert Gilmore	do	600	Dr	37	6	do
	Lewis Township							
160	Bodines	Christine R. Lewis	do	760	Dr	81	6	White sand
161	Trout Run	Dewart Milk Products Co.	do	680	Dr	120	8	Red sandstone

Lycoming County

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	45	—25	H	3±	D	Mostly drilled wells on east side of Pine Creek—some on higher ground 80 feet deep. Shallow dug wells west of creek.
Pocono	?	—30±	H	5±	D	Went dry when 78 feet but not after deepening.
Catskill	20±	—125	B	3±	D	
do	10±	—7 to —50	H	3±	D, S	Seasonal water level fluctuation. All drilled wells near Oregon Hill 30 to 360 feet deep.
Pleistocene	35	—14±	H	5±	D	
Catskill	?	— ?	N	--------	N	Formerly supplied tannery.
Pleistocene	30	—26	H	5±	D	Few nearby drilled wells—most people use springs.
Catskill	92	— ?	S	15	P	Water contains little iron and has reported hardness of 70 parts per million.
do	40±	—30	P	21	C, In	Water reported soft. 150-foot well yields 35 gallons a minute.
Pleistocene	40	—20	A	10	D	Reported tested at 20 gallons a minute.
do	75	—15±	S	6	D	
do	43	—33	H	2	D	Well to be deepened for larger yield.
do	49	—30	H	20	D	
do	37	—20	H	20	D	
do	81	—14	S	7½	D	81 feet of hardpan overlies sand. Mostly shallow driven wells in Bodines.
Catskill	?	—15	P	--------	C	Large yield reported.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Lewis Township —Continued							
162	Trout Run	Lycoming Valley Dairy	Valley	660	Dr	72	6	Sandstone or shale
163	do	William Lusk	do	670	Dr	45	6	Red shale
164	0.2 mile southwest of Trout Run	Rose Valley Fruit Farm	do	680	Dr	280	6	do
165	0.4 mile north northeast of Powys	Harry A. McKentire	do	640	Dr	63	6	Gravel
	Cogan House Township							
166	0.3 mile east of Steam Valley	C. C. Custer	Hillside	1,690	Dr	85	6	Red sandstone
167	2 miles east northeast of Cogan House	George W. Danley	do	1,700	DD	73	6	Red shale
168	White Pine	Methodist Parsonage	Upland	1,560	Dr	132	6	Red sandstone
	Watson Township							
169	1.5 miles south of Ramseyville	Dr. Senn	Valley	580±	Dr	46	6	Red shale
	Hepburn Township							
170	Cogan Station	Mrs. Swiker	do	600	Dr	46	6	Gray sandstone
	Eldred Township							
171	Warrensville	Mrs. Strobel	do	720	Dr	53	6	Red shale
	Upper Fairfield Township							
172	0.5 mile south of Loyalsock	George Fischer	do	600	Dr	43	6	Gravel
173	Farragut	Methodist Episcopal Church	do	600	Dr	124	6	Red and Gray sandstone
174	1 mile west of Fairfield Center	Louis Miller	do	710	Dr	55	6	Hard red shale
	Mill Creek Township							
175	0.3 mile northwest of Huntersville	Charles Mutehler	Saddle	1,100	DD	72	6	Red shale
	Shrewsbury Township							
176	0.7 mile west of Glen Mawr	Point School	Valley	720	Dr	70	6	Sand
177	North side of Picture Rocks	Picture Rocks Spring Water Co.	do	700	Dr	296	8-6	Brown sandstone

Lycoming County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	30	—12	S	3	C, In	30 feet of gravel cased. Reported drawdown 6 feet pumping 20 gallons a minute. Water contains some iron and is soft. See analysis. Temp. 50° F.
do	9	—6	H	5±	D	9 feet of gravel cased. Water in opening at 44 feet. Reported drawdown 20 feet pumping 50 gallons a minute.
do	11	—19	P	35	C, In	Water level measured July, 1932. Reported drawdown 49 feet.
Pleistocene	63	— ?	H	5±	D	63 feet of sand cased.
Catskill	15	—30	H	3+	D	
do	53	— ?	H	1½	D	Dug 25 or 30 feet—remainder drilled.
do	10±	—30	H	5±	D	
do	?	—12	H	3±	D	Some sand and gravel cased.
Chemung	27	—15	S	3	D	27 feet of gravel cased.
Catskill	45	—15	H	5±	D	45 feet sand and gravel cased. Reported tested at 25 gallons a minute. Similar to other wells in Warrensville.
Pleistocene	43	—26	P	5±	D	
Chemung	48	—35	H	5	D	48 feet of "hardpan" cased—very little gravel.
Catskill	5	—5	H	2	S	
do	25±	—35±	H	4	D	
Pleistocene	70	—10	H	5	D	
Chemung	52	—38	P	50	P	40 feet of clay cased. 3 gallons a minute at 65 feet, 25 at 200 feet. Reported drawdown 42 feet at 50 gallons a minute. Water level measured March, 1926.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Penn Township							
178	Northwest shore of Beaver Lake	Lesley Freulich	Valley	920	Dr	83	6	Red Shale
179	2.5 miles south of Strawbridge	Harry Kepner	Hillside	1,080	Dr	135	6	do
	Wolf Township							
180	Northwest side of Picture Rocks	Picture Rocks Picnic Ground	Valley	680	Dr	24	6	Boulders
181	Picture Rocks	Burrows Bros. Furniture Co.	do	640	Du	20	120	Gravel
182	0.6 mile south of Bryan Mill	Charles Yeagle	do	620	Dr	62	6	Gray sandstone
183	0.5 mile north of Hughesville	Hughesville Home Water Co.	do	600	2 Dr	96	4	Gravel
184	Hughesville	J. K. Rishel Furniture Co.	do	580	Dr	64	6	Black shale
185	0.5 mile northwest of Hughesville	B. F. Kahler	Hillside	640	Dr	70	6	Black slate
186	0.8 mile west of Hughesville	Jack Artley	Slope	620	Dr	32	6	Gray shale
	Muncy Township							
187	1.7 miles northeast of Pennsdale	H. B. Elliot	Canyon	680	Dr	50	6	do
188	Chippewa	Henry Kilgas	Valley	540	Dr	40	6	Gravel
189	0.7 mile south southwest of Pennsdale	Yetter Bros.	Knoll	570	Dr	135	6	Red shale
190	0.8 mile southeast of Halls	C. W. Sones	do	580	DD	135	6	Gray shale
191	0.6 mile west of Halls	Harry Brock	Valley	510	Dr	237	8	Black flinty limestone
	Fairfield Township							
192	2.5 miles east of Montoursville	H. A. Miller	Knoll	620	Dr	200	6	Soft gray slate
193	0.8 mile east of Montoursville	J. Harry Rakestraw	Valley	540	Dr	40	6	Sandstone and limestone
194	North end of Montoursville	Montoursville Water Co.	do	540	Du	30±	130±	Gravel and boulders
195	Montoursville	Russell Drick	do	530	Dr	85	6	Black flinty limestone

Lycoming County—Continued

bearing bed / Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	5	—18	H	5	D	
do	7	—75	H	1	D	Location not checked.
Pleistocene	24	—10±	H	15	D	
do	20	—10 to —15	S	80	In	Curbed with stone. Reported small drawdown. Use boiler compound.
Portage	22	—10	H	10±	D	22 feet of boulders cased.
Pleistocene	96	—4½	S	300	P	Aggregate yield 300 gallons a minute with 1½ feet drawdown measured in unused well 40 feet distant. On July 24, 1935, tested at 400 gallons a minute with some drawdown in nearby well. Temp. 52° F. See analysis.
Hamilton	30	—18±	S	20	D	Used only for drinking.
do	28	—15	H	6	S	
do	20	—5	H	10±	D	
Portage	8	—10	H	4	D	
Pleistocene	40	—10	H	10±	D	
Cayuga	45	—40	H	5±	D, S	Reported tested at 20 gallons a minute.
do	40	—40	P	2½	S	40 feet of yellow clay cased.
do	42	—25	P	9	D	Red shale 42 feet, soft gray shale 48 feet, remainder limestone. Very little water in shale.
do	100	—124	P	10	D	100 feet clay or "hardpan" cased. Water at 196 feet. Reported drawdown 40 feet pumping 25 gallons a minute.
Oriskany and Helderberg	37.5	— ?	N	3±	N	Gravel and sand cased.
Pleistocene	30±	—20±	S	350	P	Curbed with stone. Reported drawdown 5 or 6 feet. Water reported soft.
Cayuga or Helderberg	54	—20	A	25	C, In	54 feet of water-bearing sand and gravel cased owing to nearby cesspools. Reported drawdown 20 feet.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Loyalsock Township							
196	1.1 miles east of Williamsport City limits	Frank M. Haug	Valley	500	Dr	330	8	Gravel and limestone
197	Just east of Williamsport City limits	John Peters Packing Co.	do	520	Dr	186	8	Black shale ?
198	do	Harry McDaniels Dairy	do	520	Dr	46	6	Gravel
199	do	Charles Williams	do	530	Dr	50	6	Black slate
200	0.6 mile north of northeast corner of Williamsport	Silas Wheeler	Ridge	820	Dr	212	6	do
	City of Williamsport							
201	1200 Almond Street	Edward W. Lewis	Valley	540	Dr	153	8	Black shale
202	406 Bridge Street	Williamsport Narrow Fabric Co.	Slope	550	Dr	186	6	Hard black limestone ?
203	252 W. Fourth Street	Sun-Gazzette Co.	Valley	530	Dr	62	6	Gravel
204	739 First Street	Stewart Artificial Ice Co.	do	520	Dr	189	6	Black flinty limestone
205	do	do	do	520	Dr	244	8	White sandstone
206	1201 W. Third Street	J. K. Rishel Furniture Co.	do	520	Dr	50	6	Gravel
207	do	do	do	520	Dr	140	6	Soft black shale
208	Municipal Golf Course	Williamsport Water Co.	do	520	8 Du	27.7 to 31.6	312	Gravel and sand
209	Southeast part of Newberry	J. K. Mosser Leather Co.	do	520	2 Dr	600	6	Black slate
210	do	do	do	520	4 Dr	32 to 35	8	Gravel
211	1 mile west of Newberry	Keystone Glue Co.	do	540	Du	55	360	do
212	do	do	do	540	2 Dr	61	28	Sand and gravel

Lycoming County—Continued

Geologic horizon (bearing bed)	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene and Helderberg	87	—13	N	125	N	87 feet of gravel cased, but casing later raised to admit water from gravel. Gravel underlain by limestone containing some water in channels. Owner wanted 250 gallons a minute for irrigation.
Marcellus	?	—10±	A	300	C	
Pleistocene	42	—11	S	16	C, In	Gravel underlain by 4 feet of black shale. Reported drawdown 6 feet pumping 50 gallons a minute.
Marcellus	38.5	— ?	H	5±	D	38 feet of unconsolidated material cased.
Portage	?	— ?	P	6	D	
Hamilton	34	—13	T	100+	Ir	
Tully ?	62	—24	A	14	D	Used only for drinking. Reported hardness 116 parts per million.
Pleistocene	62	—10±	S	20	C, D	Drawdown reported very small. Reported hardness 106 parts per million.
Onondaga	48	—22	A	75	N	48 feet of gravel cased. Large drawdown. Water reported to contain iron.
Oriskany	50+	—22	T	400	C	50 feet of gravel cased. Sandstone overlain by black flinty limestone. Reported drawdown 50 feet. Water reported hard and iron-bearing.
Pleistocene	50	—20	S	70	C, D	Temp. 58° F. Water reported hard.
Marcellus	60	—30	N	40—	N	60 feet of sand and gravel cased.
Pleistocene	27.7 to 31.6	— ?	4 S	870	P	Average yield per well, aggregate 7,000 gallons a minute. Curbed with masonry, sealed by concrete in upper part down to layer of "hardpan."
Marcellus ?	70±	—6	A	240	N	About 70 feet of sand and gravel cased.
Pleistocene	32 to 35	—10±	S	135	In	Aggregate yield about 300 gallons a minute.
do	42	—25	T	250	In	Concrete caisson well to bedrock, lower 13 feet filled with coarse gravel to prevent caving. 500-foot well to bedrock is very weak.
do	55	—25	T	225	In	Lower 8 to 10 feet of casing slotted and gravel-packed. Each well yields 225 gallons a minute with small drawdown. See log.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Old Lycoming Township							
213	Garden View	Mr. Kershner	Valley	540	Dr	36	6	Gray slate
214	do	Philip Antis	do	550	Dr	318	6	Black slate
215	0.6 mile west of Garden View	O. F. Kilmor	Slope	660	Dr	175	6	do
	Woodward Township							
216	1.5 miles west northwest of Newberry	L. L. Dowdy	Canyon	580	Dr	48	6	Black shale
217	Linden	Mr. Ott Grove	Slope	580	DD	335	6	Blue flinty limestone
218	0.2 mile west of Linden	H. F. Fritz	do	620	Dr	97	6	do
219	0.3 mile west southwest of Linden	Paul Grove	do	600	Dr	140	6	do
220	1.3 miles southwest of Linden	A. D. Brown	do	580	Dr	72	6	Black slate
	Piatt Township							
221	Larryville	W. P. Steinbacher	Valley	560	Dr	48	6	do
222	Larrys Creek	Joseph Gray	do	540	Dr	60	6	Blue limestone
	Porter Township							
223	0.1 mile north of Jersey Shore Borough line	Crystal Ice and Coal Co.	do	580	Dr	117	6	Shale
224	Just northwest of Jersey Shore Borough line	John Lehman	Canyon	590	Dr	80	6	Black slate
	Limestone Township							
225	1.3 miles north northwest of Oriole	Barclay Bros.	Valley	650	Sp			Channel in limestone
	Armstrong Township							
226	West Borough line of Duboistown	Floyd Brennan	Hillside	600	Dr	111	6	Gray sandstone
227	do	Frank Bennett	do	600	Dr	101	6	Red Shale
228	South Williamsport	Williamsport Milk Products Co.	Valley	520	Dr	85	10	Gravel
229	Southeast part of South Williamsport	William McGinis	Hillside	620	Dr	144	6	Soft sandstone
230	do	William Kaufman	do	640	Dr	113	6	Red shale
231	1.4 miles southeast of Sylvan Dell	Otto B. Plasan	Mountain pass	1,200	Dr	48	6	Sandstone

Lycoming County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Portage	27	—15	P	3	D	27 feet of gravel cased.
do	17½	—25±	N	15	N	
do	40±	—55	P	5±	D	
do	?	+2	F	1±	N	Water contains considerable hydrogen sulphide and deposits white sulphur.
Tully	40	—40	H	½	D	A nearby well encountered a solution channel yielding considerable more water.
do	67	—40±	H	½	H	Sand and gravel cased.
do	110	—30±	P	3	D	110 feet of sand, gravel, with some clay, cased.
Hamilton	30	—30	H	2½	D	30 feet of yellow clay cased.
do	?	—43	H	--------	D	
Tully	22	—10	S	10	In	
Hamilton	?	—50	P	38	C	Water contains hydrogen sulphide, and deposits white sulphur. Temp. 53° F. See analysis.
do	28	— ?	H	--------	D	
Middle Ordovician	--------	--------	F	2,300	N	Nippono Spring. Discharge measured one mile downstream October 1, 1932, during very dry period, by Capt. E. S. Chase.
Cayuga or Clinton	65	—40	H	5±	D	65 feet of clay and boulders cased. Water reported soft.
do	73	—82	P	10±	D	73 feet of clay cased.
Pleistocene	75	—30±	T	125	C	Water reported hard.
Cayuga	97	—62±	P	50	D, Ir	97 feet of gravel and boulders cased. Reported drawdown 12 feet after 6 hours pumping 100 gallons a minute.
do	87	—45±	H	2½	D	87 feet of gravel and boulders cased.
Tuscarora	40	—4±	S	4	D	Reported tested at 18 gallons a minute. Temp. 50° F. Water very soft. See analysis.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Brady Township							
232	0.9 mile west of Fritz.	Bruce Waltman ----	Hill ------	620	Dr	135	6	Limestone ---------
	Clinton Township							
233	1.3 miles northeast of Maple Hill -----------	Merle Paige ---------	Slope -----	700	Dr	138	6	Red shale ----------
234	Montgomery ----------	I. A. Groom Dairy -	Valley ----	510	Dr	30	6	--------------------
235	do ----------	G. M. Staib Dairy -	do ----	500	Dr	105	6½	Blue sandstone ---
236	0.8 mile north of Montgomery --------------	Frank Mitsker ------	Slope -----	630	Dr	126	6	Limestone ---------
237	0.8 mile southwest of Muncy Station ------	Clayton Heilman ---	Valley ----	510	Dr	40	6	Gray shale --------
238	0.9 mile west of Muncy Station --------------	State Industrial Home for Women.	Slope -----	540	Dr	30	10	Gravel ------------
239	do	do	do -----	540	Dr	71	10	do ------------
	Muncy Creek Township							
240	Just north of borough line of Muncy --------	Muncy Water Supply Co. ---------------	Valley ----	480	4 Dr	80–140	8	Red shale ---------
241	Muncy ----------------	William Bauzhof Ice Cream Co. --------	do ----	500	Dr	113	8–6	Soft limestone ----
242	do ----------------	Muncy Pure Ice Co.-	do ----	500	Dr	302	8	Limestone ---------
243	0.2 mile east of south part of Muncy ------	Muncy Water Supply Co. ---------------	do ----	520	Du	22	216	Gravel ------------
224	1.7 miles southeast of Clarketown ----------	J. R. Opp ----------	do ----	580	Dr	98	6	Gray shale --------
	Franklin Township							
245	1 mile south southwest of Lairdsville -------	Chester Burkhart ---	Hillside --	1,000	Dr	140	6	do --------
246	Lairdsville ------------	Alvin Meyers (Grist Mill) -------------	Valley ----	740	Dr	32	6	Gravel ------------
	Jordan Township							
247	0.4 mile south of Unityville ----------------	---------------------	Hillside ---	1,280	Dr	42	6	Red shale ---------

[1] Dr, drilled well, Du, dug well; DD, dug and drilled well, Sp, spring.

[2] A, air lift; B, bucket and rope; F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated; T, turbine pump; W, windmill.

[3] C, cooling or condensing; D, domestic; In, industrial; Ir, irrigation; N, none; P, public supply; S, stock.

[4] Altitude from Ralston Water Co.

Lycoming County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Helderberg ?	53	—35	H	3±	D, S	53 feet of sand and gravel reported cased.
Clinton or Cayuga	90	—35	P	3	D, S	90 feet of dry boulders and gravel cased.
?	?	—25	S	10±	C	Water level measured July 25, 1935, while pump was running.
Portage	55	—34	A	12	C, In	Less than 40 feet of sand and gravel cased. Water reported hard.
Cayuga	115	—60	W	8	D, S	60 feet of sand, gravel, and boulders, and 55 feet of channelled limestone cased.
do	35	—18	S	4	D	35 feet of sand cased. Water reported soft.
Pleistocene	30	—12	T	75	D	Reported hardness 14-26 parts per million.
do	71	—12	T	100	D	Reported hardness 18 parts per million.
Cayuga	28–34	—6±	A	160	P	Two 80-foot and two 140-foot wells, 50 feet apart—aggregate yield given, but each well will yield nearly this amount if pumped separately. See log of well No. 1.
do	80	—35	P	25	C	Harder water near surface cased-off.
do	45	—13	T	150	C	45 feet gravel cased. Water enters at 302 feet. Reported drawdown 29 feet after 1 hour pumping 130 gallons a minute. Temp. 53° F. Water hard. See analysis.
Pleistocene	22	—5±	S	400	P	Curbed with stone. Reported drawdown 14 feet after 12 hours pumping 400 gallons a minute. A 500-foot drilled well at this locality yielded less than 50 gallons a minute.
Portage ?	18	—33±	N	3	N	
Chemung or Portage	28	—75	H	3	D	
Pleistocene	32	—12	P	5	D	
Chemung	--------	—	H	3±	D	

McKEAN COUNTY

[Area, 987 square miles. Population, 55,167]

GEOGRAPHY

McKean County lies in the northwest corner of the area described, and is bordered on the north by New York State. Among the 8 counties described in this report, McKean County ranks second in density of population with about 56 inhabitants per square mile. Bradford, with 19,306 inhabitants, is the second largest city in the area. The largest boroughs include Kane with 6,232 inhabitants; Port Allegany, with 2,193; and Eldred, Mt. Jewett, and Smethport, with 1,100 to 1,800. Most of the county is forested, and only 18.8 percent of the total land area is devoted to farming. McKean County contains most of the world-famous Bradford oil field, and is the leading oil-producing county of Pennsylvania.[71] (see plate 9B). Considerable petroleum is refined in the county, the principal refineries being at Bradford, Farmers Valley, and Eldred. According to the Federal census of 1929, McKean County had 119 manufacturing establishments whose annual products were valued at $37,494,333. Of the 119 establishments, 53 are in Bradford and produced nearly 50 percent of the total output. Most of the industries are located in the main valleys, but some are on the high plateau, at Mt. Jewett and Kane. A little coal is mined in the southern part of the county. There are numerous shallow gas fields, and there exists a good possibility of obtaining gas at considerable depth from the Oriskany sand.[72]

The topography in McKean County is characterized by a high, nearly flat plateau deeply dissected by streams but still containing considerable expanses of plateau surface, as shown in plate 3B. Prospect Hill, in Keating township, stands 2,460 feet above sea level and is the highest point in that part of the county that has been mapped topographically. The lowest point, where Kinzua Creek enters Warren County, is 1,260 feet above sea level. The maximum relief therefore is about 1,200 feet.

All but a small area at the southeast corner lies in the Ohio drainage basin, and is drained mainly by the Allegheny River and in part by the Clarion River. The southeast corner is drained by Sinnemahoning Creek, a tributary of the West Branch of the Susquehanna River.

GEOLOGY

The consolidated rocks exposed in McKean County range in age from the Chemung formation of Upper Devonian age (oldest) to the Allegheny formation of Pennsylvanian age. The Chemung formation, which contains the oil sands of the Bradford field, is exposed only along the main valleys in the northern part of the county. The Cattaraugus (plate 8B) and the Oswayo formations occupy the walls of the valleys, and the hard Knapp, Pocono, and Pottsville formations form the high plateau. The Allegheny formation is preserved from erosion on the plateau locally along synclinal axes.

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[71] Fettke, C. R., Bradford Oil Field: Pennsylvania Topog. and Geol. Survey, Bull. M 21, 450 pp., 1938.

[72] Cathcart, S. H., Possibility of finding gas in the Oriskany sand in McKean County: Pennsylvania Topog. and Geol. Survey, Bull. 111, p. 1, 1934.

Only the extreme northeast corner of the county, northeast of Oswayo Creek, was covered by the Wisconsin glacier. However, as shown on plate 2, glacial lake deposits fill the valleys of all the north-flowing streams, including the Allegheny River, Oswayo Creek, Potato Creek, Marvin Creek, and Tunungwant Creek. The known thicknesses of these deposits are shown in plate 2.

The geologic structure in McKean County is characteristic of the Plateaus province and comprises a series of folds trending northeast, as shown in plate 4. The Bradford anticline, which contains the Knapp Creek Dome and the Simpson Anticline, form the Bradford oil field. The structural details in relation to the occurrence of gas and oil have been described by Cathcart[73] and Fettke.[74]

GROUND WATER

The glacial lake deposits, shown in plate 2, are by far the most productive water-bearing materials in McKean County. They generally yield abundant supplies of water to properly constructed drilled wells using screens, some of the wells yielding as much as 750 gallons a minute. The character of the material is shown by the following well logs, and by other logs in figure 10 and in the descriptions of public supplies given below.

Typical log of wells of the Forest Oil Co., at Farmers Valley

[No. 307. Authority, W. H. Owens, driller]

	Depth (feet)		Depth (feet)
Soil	0–24	Gravel, up to ½ inch, with 10 per cent sand	94–104
Sand, with 40 per cent gravel (⅛ to ⅜ of an inch)	24–26	Clay	104–114
Fine sand and gravel	26–84	Quicksand	114–125
Soft, wet clay	84–94	Gravel, up to ⅜ inch, with 10 per cent sand	125–140

Log of well No. 2 of the Quaker State Refining Co., at Farmers Valley

[No. 308. Authority, W. H. Owens, driller]

	Depth (feet)		Depth (feet)
Soil	0–10	Clay	102–114
Gravel and sand	10–26	Gravel	114–119
Hardpan and clay	26–70	Hardpan and clay	119–132
Quicksand	70–84	Sand and gravel, with 5 feet of coarse gravel up to ½ inch	132–144
Clay	84–92	Clay	144–146
Sand and gravel	92–102		

[73] Cathcart, S. H., op. cit., pp. 2-4, fig. 1.
[74] Fettke, C. R., op. cit.

The Pottsville and Pocono are the most productive of the rock formations, although the Chemung may supply more wells.

Most of the industrial supplies are obtained from drilled wells, the largest supplies coming from sand and gravel. Ground water is used in large amounts by numerous industries in McKean County. The principal use is probably for recovering oil by the water-flooding method, which is described on pp. 65-67. Considerable water is also used by oil refineries, chemical plants, tanneries, ice plants, and dairies.

Domestic supplies are obtained largely from drilled wells or springs, but in a few places dug or driven wells are used. Considerable ground water is used for public supply, as described below.

Records were obtained of only 4 flowing wells in McKean County (nos. 281, 302, 337, 338) but other wells were reported in the vicinity of wells 283, 302, and 337, and the water levels in several other wells such as nos. 275 and 285, stand at or near the surface. Well 281 is the only flowing well observed that obtains water from sand or gravel. The most likely localities for flowing wells are the synclinal areas (plate 4). The so-called spouting or geyser wells reported many years ago near Kane are described on another page. The fluctuations of the water level in well 316 at Smethport are discussed on page 39 and shown in figure 6.

Analyses of 6 samples of water from the geologic formations in McKean County are given below. The quality of water to be expected in the formations in the county is summarized on pages 74, 75. Some of the ground waters in McKean County contain iron in objectionable amounts. The high iron content of 2 of the 3 samples from Pleistocene deposits is characteristic of such waters in certain valleys, whereas in other valleys these waters contain very little iron. Iron-

Analyses of ground waters from McKean County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in plate 2]

Number	258	266	297	317	342	350
Geologic horizon	Pleistocene	Chemung	Pleistocene	Pleistocene	Pocono	Pocono
Silica (SiO_2)	—	—	11	—	—	—
Iron (Fe)	7.8	0.50	.01	14	1.3	—
Calcium (Ca)	25	51	12	—	45	—
Magnesium (Mg)	8.7	16	4.3	—	8.2	—
Sodium and potassium (Na+K)	16	49	Na 10 K .8	—	74	—
Bicarbonate (HCO_3)	73	203	64	65	197	7.0
Sulphate (SO_4)	7	32	6.3	4	4	6
Chloride (Cl)	47	71	4.8	17	100	1.9
Nitrate (NO_3)	.0	.10	4.0	.15	.25	3.6
Total dissolved soldis	140	319	81	[1]87	329	[1]22
Total hardness as $CaCO_3$	98	193	48	58	146	10
Date of collection, 1935	Sept. 10	Sept. 10	Sept. 10	Sept. 10	Sept. 9	Sept. 10

[1] Estimated.

bearing waters are encountered at many places in the rock formations, notably in the Pocono and Pottsville. The relation of the iron-content of waters in the unconsolidated materials to the parent rock formations is discussed elsewhere. Except for the local high-content of iron, most of the ground waters in McKean County are satisfactory for all ordinary purposes.

PUBLIC SUPPLIES

Ten communities in McKean County have public water-supplies, all of which use some ground water and 6 of which are supplied wholly with ground water.

Bradford (population 19,306) is supplied by the Bradford Municipal Water Works. The principal supply comes from Gilbert Run and Marilla Brook, two small streams about 3½ miles west of the city. Gilbert Run, which supplies 0.02 to 1.0 million gallons a day, is impounded by a dam forming reservoir no. 2, which holds 202 million gallons. Marilla Brook, which supplies 2.5 to 3.3 million gallons a day, is also dammed, the reservoir (no. 3) holding 325.5 million gallons. The water from these reservoirs flows by gravity to the distributing mains, and part of it fills reservoir no. 4, at the north end of the city, which holds 3.5 million gallons. The average pressure at the service taps and at the 250 fire hydrants is 80 pounds per square inch. The average daily consumption is 3 million gallons, 87.5 percent of which is used by manufacturers and railroads. The water from the streams is chlorinated as it leaves the reservoirs. When the streams are low, an auxiliary supply is furnished by 11 drilled wells, only 9 of which are now in use. The 2 Marilla Brook Wells (nos. 250, 251) are in the Cattaraugus formation (see log below), and are no longer used as they can be pumped dry at the rate of 125 gallons a minute. The 9 wells used all end in sand or gravel. The 6 Bennet Street wells (no. 257) are open-end wells, and are pumped by a suction pump at an aggregate rate of 500 gallons a minute. The Mill Street well (no. 260) contains a gravel-packed screen and is pumped by a turbine at the rate of 550 gallons a minute. The 2 newest wells(nos. 256, 257) utilize gravel-packed screens as shown in figure 10, and each is pumped by a turbine at the rate of 635 gallons a minute.

Log of Marilla Brook Well No. 3 of the Bradford Municipal Water Co., 3.3 miles west of Bradford

[No. 251. Authority, Pennsylvania Department of Health]

	Depth (feet)		Depth (feet)
Soil	0–3	Clay, yellow	36–53
Gravel	3–7	Slate, blue	53–73
Clay, sand and gravel	7–14	Sandstone, white, fossiliferous	73–83
Gravel (first water)	14–30	Slate, blue, fossiliferous	83–101
Clay	30–32	Shale and sandstone, red	101–140
Gravel (water)	32–36	Slate, blue	140–160

Eldred (population 1,118) is supplied by the Galeton-Eldred Water Company, which also supplies Galeton in Potter County. The principal supply comes from 4 hillside springs about 2 miles east of the borough, known as the Biggins, Welsh, Toole Pocket no. 1, and Toole Pocket no. 2 springs. The springs discharge into a 60,000-gallon concrete reservoir, whence the water is distributed by gravity at an average pressure of 90 pounds per square inch. There are 36 fire hydrants. All of the water is used for domestic purposes, and the daily consumption is not known as no meters are used. Additional water when needed can be pumped directly into the mains from 5 drilled wells in the borough which end in gravel. There are also one or two old wells that are no longer used. Four shallow open-end wells (no. 282) connected to one electrically-driven suction pump together yield 50 gallons a minute, and one deeper well (no. 283) drilled in 1934 contains a strainer and is equipped with a similar pump. This well, the log of which is given below, is pumped at the rate of 50 gallons a minute, but on test is reported to have yielded 390 gallons a minute with a drawdown of 9 feet. Neither the spring nor well water is treated. During the drought in 1930 (before well 283 was drilled) the springs and wells combined were inadequate to supply the borough, and it was necessary to obtain additional water from 5 shallow wells owned by the Pennsylvania Railroad. In 1935, however, the springs supplied all the water requirements except during a ten-day period when some of the wells were pumped.

Log of well of the Galeton-Eldred Water Co., at Eldred

[No. 283. Authority, Pennsylvania Department of Health]

	Depth (feet)		Depth (feet)
Sand and gravel	0–37	Gravel	71–75
Gravel	37–42	Hardpan	75–89
Clay and hardpan	42–48	Clay	89–99
Gravel	48–53	Gravel	99–111
Clay, hardpan, and gravel	53–71	Clay	111–112.7

Foster Brook is supplied by the Case Land Company from 2 open-end drilled wells in gravel (no. 265). Each well is equipped with an electrically driven suction pump and yields 95 gallons a minute; only one well being pumped at a time. The water is distributed from two 1,600-gallon pneumatic tanks at pressures ranging from 35 to 50 pounds per square inch. There are 3 fire hydrants. The average daily consumption is 27,000 gallons, all of which is used for domestic purposes. The water is not treated.

Kane (population 6,232) is supplied by the Kane Spring Water Company. The main supply comes from 3 springs that issue from the Pocono formation along Hubert Run north of the borough and about 300 feet lower than most parts of the borough. One spring is near the dam, reservoir, and pump station, the other two are ¾-mile upstream. The water from the springs flows by gravity into the reser-

voir, which holds 600,000 gallons, whence it is pumped up into the mains by one of three triplex pumps driven by natural gas engines, with capacities of 700, 700 and 350 gallons a minute. The excess water fills a 150,000-gallon standpipe at the southeast corner of the borough. The pressure at the service taps and at the 75 fire hydrants ranges from 40 to 135 pounds per square inch. The water is chlorinated as it enters the suction line to the pumps. An auxiliary supply is furnished by 17 drilled wells (no. 331) located along Hubert Run, a typical log of which is given below. The wells are pumped by air lift, the air being supplied by 2 compressors in the pump station, and each well yields 100 to 150 gallons a minute. Generally about 10 of the wells are pumped 4 hours daily for about 5 months of each year. A separate source of water from Hubert Run is used to supply about 35,000 gallons a day to the Pennsylvania Railroad. The dam near the pump station impounds 700,000 gallons, whence it is pumped by one of the 3 pumps through a separate main to the railroad watering tanks.

Log of well No. 14 of the Kane Spring Water Co., near Kane

[No. 331. Authority, Mr. Russell, Superintendent]

	Depth (feet)		Depth (feet)
Surface	0–6	Slate	105–130
Clay	6–32	Fine grained blue sandstone	130–206
White sandstone (first water)	32–70	Coarse gray sandstone (water-bearing)	206–250
Pebble conglomerate	70–105	Slate	250–268

Lewis Run (population 837) is supplied in part by the privately-owned Lewis Run Water Company, from one spring that issues from shale in the Cattaraugus formation south of the borough. The water flows into a 250,000-gallon concrete reservoir whence it is distributed by gravity at a pressure of 45 or 50 pounds per square inch. There are 9 fire hydrants. The water is not treated. Families living east of the creek are supplied with surface water by the Hanley Brick Company.

Ludlow is supplied in part by the J. G. Curtis Leather Company from 6 small springs north of the village, 5 of which are along Windfall Run. The water flows by gravity into 2 steel distributing tanks on the company's property, each of which holds 250,000 gallons. Part of the water is used by the company, which is also supplied from 2 drilled wells (no. 329). The water is not treated. Several other

springs supply other groups of homes in Ludlow through separate systems.

Mt. Jewett (population 1,379) is supplied by the Mt. Jewett Water Company from a group of springs and 4 drilled wells, all of which are near the reservoir and pumping plant in a deep canyon east of the borough. The discharge of 5 of the springs (no. 350) which all flow into one small collecting basin, was measured by the writer on September 7, 1935 and found to be 62 gallons a minute. Most of the other springs each yield 5 to 10 gallons a minute. The 4 drilled wells (nos. 346-349) are pumped by air lift and yield a total of about 60 gallons a minute. The springs generally supply all the water needed—the wells being required only a few weeks during 1934 and not at all during 1935. The water from all sources is collected in a 40,000-gallon masonry reservoir, whence it is pumped up to the borough which is about 300 feet higher than the pumping plant. The equipment in the pumping plant includes one large triplex force pump driven by a natural gas engine, a smaller diesel-driven force pump for emergency use, and an air compressor for pumping the wells. The excess water is stored in two 50,000-gallon concrete tanks in the southwest part of the borough. The pressures at the service taps and at the 37 fire hydrants ranges from 45 to 60 pounds per square inch. The average daily consumption is 50,000 to 75,000 gallons, most of which is used for domestic purposes. The water is chlorinated, and is very soft as shown by analysis 350 of the spring water.

Port Allegany (population 2,193) is supplied by the privately-owned Port Allegany Water Company. The main supply comes from

Logs of wells of the Port Allegany Water Co., at Port Allegany

[No. 296. Authority, F. F. Fairbanks, Superintendent]

Wells 1 to 4, drilled in 1910	Depth (feet)
Hardpan	0–12
Gravel	12–14
Yellow clay	14–20
Gravel	20–25
Yellow clay	25–38
Gravel	38–44
Yellow clay	44–60
Gravel	60–65
Yellow clay	65–85
Blue clay	85–95
Gravel	95–106
Yellow clay (casing ends)	106–116
Blue clay	116–133
Blue slate	133–161
White sandstone	161–180

Well 5, drilled in 1924	Depth (feet)
Gravel	0–35
Gravel and clay	35–70
Gravel, some water	70–75
Fine gravel, water	75–95
Fine sand	95–125
Slate, sandstone and shells (cased to slate)	125–135
Shells (water at 135)	135–155
Well 6, drilled in 1924	
Gravel (water red at 47 feet)	0–47
Clay and coarse gravel	47–70
Fine gravel, some water	70–100
Fine sand and fine gravel	100–127
Slate, sandstone and shells (cased to slate. Water at 130 and 160 feet)	127–171

Godding Run, Paul Brook, and Sherwood Branch, three small tributaries of Skinner Creek, west of the Allegheny River and into which they flow. Dams across each of the three streams form reservoirs holding respectively 1,000,000, 182,000, and 102,000 gallons. A fourth reservoir at the mouth of Sherwood Branch holds 855,000 gallons, and is used only in emergencies. The water from the three reservoirs is distributed by gravity, the pressures at the service taps and at the 57 fire hydrants being 80 to 90 pounds per square inch. The average daily consumption is 300,000 gallons, nearly all of which is used for domestic purposes. An auxiliary supply is furnished by 6 drilled wells (no. 296) in the borough which tap the Chemung formation (see logs below). The wells are pumped by air lift and together yield 250 gallons a minute. The water is collected in a small basin whence it is pumped directly into the mains by triplex pump, capacity 350 gallons a minute. The pump and air compressor are powered by natural-gas engines. In 1934, 5 of the wells were pumped from June 1 to November 1, but in 1935 the wells had not been pumped up to September 3, when the plant was visited. The surface water is chlorinated, but the well water is not treated. A few houses in the northern part of the borough are supplied with surface water from an old supply formerly owned by a tannery.

Rixford is supplied by the Rixford Water Works Association from one drilled well (no. 276) which obtains water from gravel. The turbine in the well pumps the water at the rate of about 100 gallons a minute into a 4,800-gallon tank, whence the water is pumped directly into the mains by triplex pump at the rate of 35 gallons a minute. The excess water fills a 5,000-gallon steel tank 209 feet higher than the pumping station. The system serves 200 people, and the water is all used for domestic purposes. There are no fire hydrants. The water is not treated.

Smethport (population 1,733) is supplied by the privately-owned Smethport Water Company. The principal supply comes from Blacksmith and Sheldon Brooks, 2½ miles west of the borough. Two reservoirs, formed by dams across the brooks, hold a total of 1,350,000 gallons. The water is distributed by gravity at pressures of 15 to 90 pounds per square inch. Similar pressures exist at the 40 fire hydrants. The average daily consumption is 200,000 gallons, most of which is used for domestic purposes. About 3 months each year, additional water is obtained from one auxiliary drilled well (no. 319) in the borough. The turbine in the well pumps the water directly into the mains at the rate of 160 gallons a minute. The water from all sources is chlorinated. The McKean County Home, just southwest of the borough, has an independent supply from one drilled well (no. 320).

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Corydon Township							
248	4 miles east southeast of Corydon	Civilian Conservation Corps Camp No. 14	Valley	1,500	Dr	200	6	Slate
249	4.5 miles west northwest of Marshburg	Civilian Conservation Corps Camp No. 5	do	1,560	Dr	145	6	do
	Bradford Township							
250	3.8 miles west of city limits of Bradford	Bradford Municipal Water Co.	Canyon	1,700	Dr	124	8	Sandstone
251	3.3 miles west of city limits of Bradford	do	do	1,660	Dr	160	8	do
252	2.2 miles southwest of Custer City	Healy Petroleum Co.	Hillside	2,160	Dr	285	8	Gray sandstone
253	0.5 mile east southeast of Degolia	Forest Oil Co.	Valley	1,520	Dr	309	6	do
254	2 miles southwest of city limits of Bradford	do	do	1,500	Dr	305	12–8	Gravel and sand
255	0.6 mile southwest of city limits of Bradford	Bradford Municipal Water Co.	do	1,460	Dr	121	18–12	do
256	0.5 mile southwest of city limits of Bradford	do	do	1,460	Dr	122	18–12	do
	City of Bradford							
257	Southwest part of Bradford	do	do	1,450	6 Dr	96–185	8	Coarse gravel
258	South end of Bradford	Fresh Water Ice Co.	do	1,460	Dr	255	8	Gravel
259	Central part of Bradford	General Garage	do	1,440	Dr	49	8	Gravel and sand
260	do	Bradford Municipal Water Co.	do	1,440	Dr	122	14–8	Gravel

in McKean County

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung	32	—55	P	10	D	28 feet of clay and boulders cased. Water at 45, 90, 120, 200 feet. Reported drawdown 10 feet after 24 hours pumping 25 gallons a minute.
Cattaraugus	95	—25	P	15	D	Considerable sand and gravel cased, 15 gallons a minute aggregate from gravel at 25, 55, 64, and sand at 77 feet. Reported small drawdown at 40 gallons a minute.
do	--------	—25	T	--------	N	Marilla Brook Well No. 2. Pumps dry at 125 gallons a minute.
do	53	—25	T	--------	N	Marilla Brook Well No. 3. Pumps dry at 125 gallons a minute. 53 feet of clay, sand, and gravel cased, see log.
Oswayo	30	—70	A	30	O	
Chemung	174	—20	P	5±	D	174 feet of clay and fine sand cased.
Pleistocene	[4]137	—36	T	380	O	12-inch casing to 74 feet, 10-inch well screen 74 to 93 feet, slotted 8-inch casing 93 to 137 feet. 137 to 305 feet in bedrock—not much water. Reported drawdown 5 feet at 380 gallons a minute. Water reported good.
do	89	—9	T	635	P	Finished with 32-foot screen surrounded by 7 tons of selected gravel placed between inner and outer casings—outer casing pulled back to uncover screen. Reported drawdown 6 feet after 8 hours pumping 635 gallons a minute. Water reported good. See log, fig. 10.
do	95	—4	T	635	P	Similar to well 255 with 27-foot screen and 6 tons of gravel. Reported drawdown 4 feet after 8 hours pumping 635 gallons a minute. Water reported good. See log, fig. 10.
do	80–128	—5±	S	100±	P	Bennett Street wells, open finish. Aggregate yield 500 gallons a minute from 6 wells. Water reported good.
do	[4]197	—26	T	140	C	Casing slotted in 4-foot sections opposite gravel beds at 76-80 feet, 174-178 feet, and 188-192 feet. Some water in shale at 230 feet. When new yielded 120 gallons a minute with 60 feet drawdown, now yields 140 gallons a minute with 40 feet drawdown. Water contains considerable iron, see analysis. Temp. 50° F.
do	47	—5	S	10	W	Reported drawdown 5 feet after 1 hour pumping 170 gallons a minute.
do	113	—17	T	550	P	Mill Street well. 9-foot slotted 8-inch casing surrounded by 3 tons of 1½-inch gravel. Reported drawdown 9 feet after 8 hours pumping 550 gallons a minute. Water reported hard and iron-bearing.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	City of Bradford—Continued							
261	Northeast part of Bradford	Kendall Refining Co.	Valley	1,440	Dr	233	6	Gravel
262	do	do	do	1,440	3 Dr	267	6	Shale
263	Northernmost part of Bradford	Bradford Milk Co.	do	1,440	Dr	214	6	Gravel
	Foster Township							
264	0.3 mile west of Foster Brook	Bradford Refining Co.	do	1,420	Dr	102	8	Coarse gravel
265	0.3 mile south of Foster Brook	Case Land Co.	do	1,430	2 Dr	88	8	Consolidated gravel
266	0.2 mile west of Corwins Corners	F. L. Bouquin	do	1,600	Dr	152	6	Slate
267	0.3 mile east of Corwins Corners	Forest Oil Co.	do	1,580	Dr	300	12–6¼	Gravel
268	0.6 mile east southeast of Corwins Corners	do	do	1,600	Dr	251	8	Slate
269	1 mile southeast of Corwins Corners	do	do	1,660	Dr	157	6	Gray slate
270	2 miles north of Rew	Brinck and Brinck	Ridge	2,160	Dr	236	6¼	White sandstone
271	1.3 miles west south west of Rew	Ralph George	do	2,260	Dr	165	6	do
272	0.3 mile northeast of Rew	Forest Oil Co.	do	2,140	Dr	296	6¼	Gray sandstone
	Otto Township							
273	1.1 miles north northwest of Duke Center	Redwood Oil Co.	Valley	1,620	Dr	250	8	Slate
274	do	do	do	1,640	Dr	225	8	do
275	1 mile northwest of Rixford	Forest Oil Co.	do	1,700	Dr	175	6	Sandstone
276	Rixford	Rixford Water Works Association	do	1,620	Dr	195	8–6	Gravel
277	do	Messer Oil Co.	do	1,600	Dr	320	8	White sandstone

in McKean County—Continued

Geologic horizon (bearing bed)	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	[4]233	— ?	A	75	C	Casing perforated from 220 to 230 feet. Water reported to contain 4 parts per million of iron. A nearby well with same yield is 40 feet deep and yields water with one part per million of iron.
Chemung	53	— ?	A	50	C	At edge of valley. Each well same yield, water reported good.
Pleistocene	204	—12±	T	100	C	Finished with 10 foot Layne screen. Pumps sand. No iron reported. Temp. 49° F.
do	102	—4	S	250	C	Open finish. Reported drawdown 4 feet. Water reported iron-bearing. Have 4 gravel wells and 2 bedrock wells. One 320-foot well hit bedrock at 236 feet and yielded brackish water from 285 feet.
do	88	—6	S	95	P	Open finish. Each well same yield, generally only one used. Reported drawdown 4 feet.
Chemung	79½	—24	P	4	D	Temp. 52° F. See analysis.
Pleistocene	[4]128	—25	T	700	O	Finished with 12-inch well screen 63 to 78 feet, 8-inch slotted casing 78 to 128 feet, bedrock at 128 feet, some water from bedrock. Reported drawdown 35 feet at 700 gallons a minute. Have several similar wells nearby. Water reported to contain iron.
Chemung	[4]111	—125	A	50	O	111 feet of clay, sand, and water-bearing gravel cased. Low water level (March, 1934) probably result of heavy pumping. Casing later ripped at 55 feet to allow water from gravel to enter.
do	32½	— ?	N	40±	N	Drilled for flooding oil wells but yield inadequate.
Oswayo ?	44	— ?	P	5	D	Water reported good.
Knapp	100	—100	A	10	D	Location not checked. Cased deep to avoid iron-bearing water but water still contains iron.
Cattaraugus	112	—70	P	7½	N	Cased deep to avoid gas. Formerly supplied 3 houses but water reported poor.
Chemung	52.7	—30	A	40	O	No water reported in silt and gravel cased. Reported drawdown 30 feet.
do	52.7	—9	T	100	O	Some water in gravel but inadequate. Reported drawdown 28 feet after 10 hours pumping 100 gallons a minute.
do	54	O	S	20	D	Water level reported at surface.
Pleistocene	195	—20±	T	100±	P	Reported hardness, 170 parts per million; iron 0.3 part.
Chemung	100	—70	A	100±	O	Have 5 similar wells nearby.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Otto Township—Continued							
278	Rixford	Messer Oil Co.	Valley	1,600	Dr	103	12–8	Gravel
279	do	do	do	1,600	Dr	350	8	Sandstone
280	0.4 mile southeast of Rixford	do	Canyon	1,660	Dr	800	8¼–6¼	do
	Eldred Township							
281	1.1 miles north of Bullis Mills (in New York State)	Mrs. L. M. Randell	Valley	1,440	Dr	146	6	Sand
282	Eldred	Galeton-Eldred Water Co.	do	1,440	4 Dr	31	4¼	Gravel
283	do	do	do	1,440	Dr	112.7	8	do
284	do	F. L. Woolcott	do	1,440	Dr	77	6	do
285	Just south of Eldred Borough line	Pennsylvania Oil Products Refining Co.	do	1,440	Dr	117	12	do
286	do	do	do	1,440	2 Dr	119, 53	6	do
	Ceres Township							
287	0.8 mile east southeast of Myrtle	John Danford	do	1,460	Dr	41	4	Coarse sand
288	0.2 mile west of Shinglehouse Borough line	Justin Bridge	do	1,500	Dr	60	4	Fine gravel
289	2.5 miles southwest of southwest corner of Shinglehouse	Frank Mathews	Canyon	1,700	Dr	40	4	Gray sandstone
	Annin Township							
290	2.1 miles east of Turtle Point	James Dunn	do	1,600	Dr	116	4	Gray shale
	Liberty Township							
291	0.9 mile east of Lower Open Brook School	Mrs. Fred Freer	Hillside	1,860	Dr	125	6	do
292	0.7 mile north of Port Allegany	Twomile School	Valley	1,480	Dr	49	4¼	Reddish gravel
293	0.9 mile northeast of Twomile School	Harold Thoren	Canyon	1,550	Dr	150	4¼	Gray shale

in McKean County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	[4]103	—18	N	130	N	Finished with 10-inch screen from 53 to 66 feet, 8-inch casing slotted below 66 feet. Reported drawdown 16 feet at 130 gallons a minute. Water reported corrosive, therefore not used.
Chemung	100	—29	T	200	O	Abandoned oil well plugged at 350 feet. Reported drawdown 140 feet pumping 200 gallons a minute continuously. Water from wells 279 and 280 reported to contain 310 parts per million of chloride, 0.2 part iron.
do	44	—31	T	60±	O	Abandoned oil well plugged from 800 to 1,000 feet. Reported drawdown 150 feet pumping about 60 gallons a minute continuously.
Pleistocene	146	+1½	S	5	D	Flows about 2 gallons a minute. Temp. 50° F.
do	31	— ?	S	50	P	Aggregate yield—one pump connected to 4 wells.
do	105	—2	S	50	P	Finished with Owens well screen from 105-112.7. Reported drawdown 9 feet after 3 days pumping 390 gallons a minute. Water reported to contain 50 parts per million hardness, 0.4 part iron. See log. Nearby well 212 feet deep hit bedrock at 168 feet, flows. See log.
do	77	—10±	S	25	D	Reported drawdown 10 feet.
do	108	O	S	140	C	Finished with 9-foot Owens well screen. Water level at surface. Reported drawdown 18 feet.
do	119, 53	—10±	S	98	C	Aggregate yield, pumped together, with 12-foot drawdown. Open finish, casing in deepest well perforated at 53 feet. Several other open finish wells. 147 feet to bedrock.
do	41	—3	H	10±	D	Open finish.
do	60	—58	P	8±	D	Open finish. Similar wells nearby.
Chemung	20	—32±	H	2	D	
do	106	—60±	P	10	D, S	Soft loam and clay cased. Reported drawdown about 20 feet.
Cattaraugus	26	—70	P	4	D	
Pleistocene	47	—12	H	5	D	
Chemung	117	—90	H, P	3	S	117 feet of yellow clay and some gravel cased, some water in gravel at 86 feet.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Liberty Township—Continued							
294	Port Allegany	American Extract Co.	Valley	1,480	Dr	112	8	Gravel and sand
295	do	do	do	1,480	Dr	116	8	Coarse gravel
296	do	Port Allegany Water Co.	do	1,490	6 Dr	155–180	8–6	White sandstone
297	do	Abbotts Dairies, Inc.	do	1,480	Dr	100	6	Gravel
298	do	Pennsylvania Railroad	do	1,480	Dr	110	6¼	do
299	do	Pierce Glass Co.	do	1,470	Dr	125½	8	do
300	do	Port Allegany Community Park	Slope	1,510	Dr	247	8	Brown sandstone
301	3.5 miles south southeast of Port Allegany	Fred Mantz	Valley	1,560	Dr	76	5	Gravel
	Keating Township							
302	Coryville	T. A. Hardes	do	1,450	Dr	64	4	Soft gray shale
303	Wrights Corners	Bradford Transit Co.	do	1,590	Dr	135	6	Gray shale
304	1 mile southeast of Coleville	Cecil Burgess	do	1,620	Dr	60	2	Gravel
305	1.8 miles south of Rew	Wilson and Fitzgivens	Canyon	1,780	Dr	296	6	Gray sandstone
306	0.2 mile northeast of Farmers Valley	Farmers Valley School	Valley	1,460	Dr	195	6	Sand and gravel
307	0.4 mile east of Farmers Valley	Forest Oil Co.	do	1,440	3 Dr	140	10	Gravel
308	0.2 mile east of Farmers Valley	Quaker State Refining Corp.	do	1,440	Dr	146	12	do

in McKean County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	106	—12	S	330	In	Finished with 6-foot Owens well screen. Reported drawdown 6 feet at 330 gallons a minute.
do	110	—17	S	150	In	Finished with 6-foot Owens well screen. Also water in coarse sand at 102-110 feet and in gravel at 60 feet, but water at 60 feet iron-bearing. Reported drawdown 8 feet after 34 hours pumping 250 gallons a minute.
Chemung	116–127	—25	A	250	P	Aggregate yield of 3 to 6 wells pumped together with 35 feet drawdown. See logs.
Pleistocene	95	—14	T	100	C, In	Gravel from 60 to 100 feet. Finished with 5 feet of perforated casing. Reported tested at 350 gallons a minute with small drawdown. Temp. 50° F. See analysis.
do	100	—14±	S	--------	R	Finished with 10-foot Layne well screen. Have another gravel well at Larabee.
do	115	—14	T	150	C,D,In	Finished with 10 feet of perforated 7-inch casing. Reported pumped several days at 500 gallons a minute. Formerly used 12 small jetted wells about 40 feet deep which together yielded 180 gallons a minute.
Chemung	100	—70	T	250	Sp	100 feet of soil and broken rock cased. Reported drawdown 145 feet after 48 hours pumping 250 gallons a minute.
Pleistocene	68½	—23±	P	15	D	No bedrock encountered.
Chemung	52	+6	S	5	D	Clay and some gravel cased, iron-bearing water in gravel at 14 feet. Flows about 2 gallons a minute, several other flowing wells nearby.
do	117	—17	S	4	D	Clay and gravel cased, water in gravel at 115 feet.
Pleistocene	48	—5	S	4	D	Well across street to southwest is 105 feet deep, cased 70 feet, water in conglomerate.
Cattaraugus	65	—3	A	--------	O	Very little sand or gravel. Another similar well nearby.
Pleistocene	193	—30±	P	5	D	Pumps some sand.
do	131	—5	N	750	N	Drilled for flooding oil wells but never used. Reported drawdown 9 feet after 12 hours pumping 750 gallons a minute, from each well. Finished with 9-foot Owens well screen. See log. Test well 357 feet deep encountered slate bedrock at 237 feet—water in slate reported salty.
do	140	—½	T	406	C, In	Well No. 2. Finished with 6-foot Layne well screen. Reported drawdown 36 feet after 48 hours pumping 406 gallons a minute. Formerly pumped at 600 gallons a minute, reduced yield due to clogged screen. See log.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Keating Township—Continued							
309	Farmers Valley	Quaker State Refining Corp.	Valley	1,440	Dr	140	18	Gravel
310	0.3 mile south of Farmers Valley	do	do	1,440	Dr	140	12	do
311	1.1 miles east of Farmers Valley	Mrs. Patterson	Slope	1,520	Dr	110	4¼	Gray shale
312	0.2 mile south of Bush Hill School	Charles McKearnan	Hillside	1,960	Dr	200	6¼	do
313	0.6 mile northeast of East Smethport	C. L. Oviatt	Slope	1,500	Dr	45	6	Gray sandstone
314	0.2 mile south of East Smethport	Raphael Kessler II	Valley	1,480	4 Dr	160	8	Gravel
315	0.1 mile south of southeast corner Smethport Borough line	Pete Olson	Slope	1,520	Dr	111	4	Sandy shale
316	110 North Street, Smethport	J. W. Hubbard	Hillside	1,620	Dr	72½	6	Shale
317	Smethport	McKean County Creamery	Valley	1,480	Dr	190	6	Gravel
318	South part of Smethport	J. L. Wirt	do	1,500	Dr	62	6	do
319	West part of Smethport	Smethport Water Co.	do	1,480	Dr	112	8	do
320	0.1 mile northwest of southwest corner of Smethport Borough line	McKean County Home	do	1,500	Dr	187½	12	do
321	Ormsby	?	Plateau	2,180	Dr	40	6	White sandstone
322	Backus	Newton Chemical Co.	do	2,090	2 Dr	260, 329	8	Hard gray sandstone
323	Simpson (Cyclone Post Office)	Cyclone School	do	2,220	Dr	237	6	Gray sandstone
324	do	Penn. Oil Co.	do	2,000	Dr	200	8	White sandstone
325	0.2 mile south of Davis (Gifford Post Office)	Forest Oil Co.	do	2,220	Dr	231	6¼	Hard white sandstone
	Lafayette Township							
326	Lewis Run	Valley Hunt Club	Slope	1,600	Dr	201	6	Gray sandstone
327	Irishtown	Dodge & Hilliard	Plateau	2,100	Dr	125	6¼	White sandstone

in McKean County—Continued

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	134	—14	T	391	C, In	Well No. 1. Finished with 6-foot Layne well screen. Formerly yielded 600 gallons a minute, screen believed clogged.
do	132	—4±	T	352	C, In	Well No. 3. Finished with 8-foot Layne well screen. Yield reduced—screen believed clogged.
Chemung	?	—70	H	5±	D	Reported drawdown 40 feet pumping 10 gallons a minute.
Cattaraugus	55	—140	P	2	D	
Chemung	30	—12	S	5	D	Reported tested at 40 gallons a minute.
Pleistocene	160	— ?	A	--------	N	Abandoned chemical plant. Reported strong yields. Formerly used by Smethport Water Co. in emergency.
Chemung	96	— ?	P	10	S	95 feet of yellow clay and stones cased.
Cattaraugus	?	—31.6 to —36.8	N	--------	N	Observation well. Water level measured weekly by owner. See fig. 6.
Pleistocene	190	—16	S	15	C, In	Open finish. Reported tested at 52 gallons a minute with small drawdown. Water contains considerable iron. See analysis. Temp. 51° F.
do	32	—10±	H	5±	D	32 feet of hardpan cased.
do	108	—12	T	160	P	Open finish, pumps sand at 200 gallons a minute. Reported drawdown 30 feet pumping 160 gallons a minute. A nearby well is 107 feet deep and yields only 60 gallons a minute.
do	173	—18	T	220	D	Finished with 15-foot Cook Toncan-Iron well screen. Reported drawdown 64 feet pumping 220 gallons a minute.
Pottsville	8	—20	H	2	D	
Knapp	21	—30±	A	50±	N	Plant abandoned.
do	97	—60	P	10	D	Cased-off iron-bearing water and coal streaks.
do	193	—70	H	5±	D	Iron-bearing water cased off. Reported tested at 25 gallons a minute.
do	66	—100±	P	4	D	Iron-bearing water cased off.
Chemung	126	—44	T	60	D, Sp	Iron-bearing water in gravel at 60 feet cased off. Some water at 140 feet and 160 feet, but principally at 185 feet. Reported small drawdown.
Knapp	20±	—25±	P	20	In	Reported tested at 100 gallons a minute.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Hamilton Township							
328	0.7 mile south of Dunkle Corners	Civilian Conservation Corps Camp No. 11	Hillside	1,360	Dr	206	6	Gray sandstone
329	Ludlow	J. G. Curtis Leather Co.	Valley	1,540	2 Dr	125	4	?
330	Wetmore	C. E. Keeler	Hillside	1,820	Dr	90	6	Gray sandstone
	Wetmore Township							
331	0.5 mile northeast of northeast corner of Kane Borough line	Kane Spring Water Co.	Valley	1,750	Dr	268	7⅝	Coarse gray sandstone
332	1.5 miles northeast of Kane	Walberg Bros.	Ridge	2,100	Dr	204	6	Sandstone
333	1.3 miles east of Kane	Greendale School	do	2,060	Dr	199	6	do
334	0.8 mile east of Kane	Kane Pure Ice Co.	do	2,040	Dr	350	6¼	do
335	Kane	Holgate Bros. Co.	do	2,040	Dr	256	6	do
336	Between Kane and East Kane	Ansell Nelson	do	2,050	Dr	216	6¼	White sandstone
337	0.5 mile east of Coontown	Olean Petroleum Co.	Canyon	[5]1,907	3 Dr	150	8¼	Conglomerate
338	1 mile south of Coontown	do	do	[5]1,945	Dr	165	8¼	do
339	1.2 miles southeast of Coontown	do	Ridge	[5]2,172	Dr	350	8¼	do
	Hamlin Township							
340	0.9 mile north of Lantz Corners	Hill Top Tea Room	Plateau	2,070	Dr	95	6	Shale
341	0.8 mile north northeast of Lantz Corners	Toby Springs School	Ridge	2,080	Dr	109	6	Sandstone
342	Lantz Corners	Kendall Refining Co.	do	2,100	Dr	330	10–8	Red sandstone
343	do	Big Level Inn	do	2,100	Dr	179	6	Sandstone
344	Mt. Jewett	Mt. Jewett Tanning Co.	Plateau	2,200	Dr	290	6	do
345	do	Allegheny Glass Corp.	do	2,220	5 Dr	265	6	do
346	0.5 mile east of east borough line of Mt. Jewett	Mt. Jewett Water Co.	Canyon	[6]1,945	Dr	100	7⅝	do

in McKean County—Continued

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pocono ?	64	—42	P	10	D	Reported drawdown 4 feet after 24 hours pumping 18 gallons a minute.
do ?	?	—25±	P	45	In	Each well yields this amount.
Pocono	26	—40	P	2½	D	
do	42	—30	A	150	P	Typical of 17 nearby wells, 263 to 318 feet deep, each yields from 100 to 150 gallons a minute. See log.
Pottsville	60	—70	P	3	D, S	Water reported iron-bearing.
do	119	—130	P	2	D	Iron-bearing water cased off.
Pottsville or Pocono	25±	—70±	P	25	C, In	Water contains iron, and is treated for making ice.
Pottsville	50±	—180	T	100±	In	No iron reported, water treated for boiler use.
do	164	—150	P	3	-------	Water at 87 and 163 feet containing iron and hydrogen sulphide cased off.
Pocono	21	+1	F	50	O	3 plugged oil wells—each reported to flow about 50 gallons a minute. Water reported to contain some hydrogen sulphide but no iron.
do	22	+1½	T	150	O	Reported to flow 50 gallons a minute, 11 feet drawdown pumping 150 gallons a minute. Water reported to contain some hydrogen sulphide but no iron.
Pottsville or Pocono	21	—250	T	50	O	Reported drawdown more than 80 feet.
Pottsville	21	—40	P	2	D	Reported inadequate in dry weather.
do	94	—60	H	10±	D	Water reported good.
Pocono	131	—100±	P	10±	D	6¼-inch casing surrounded by cement to case off iron-bearing water, but water contains some iron and hydrogen sulphide. See analysis.
Pottsville or Pocono	126	— ?	P	3±	D	Iron-bearing water cased off.
Pottsville	?	—60±	T	110	In	Water treated for boiler, no iron reported. Have another well same depth, not needed.
do	20	—100±	P	10±	C, In	5 similar wells, each is pumped at about 10 gallons a minute. Water reported good.
Pocono	49½	—80±	A	15±	P	Well No. 2. All four wells together yield about 60 gallons a minute.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Hamlin Township—Continued							
347	0.5 mile east of east borough line of Mt. Jewett	Mt. Jewett Water Co.	Canyon	[6]1,958	Dr	304	10	Sandstone
348	do	do	do	[6]1,984	Dr	300	7⅝	do
349	do	do	do	[6]1,977	Dr	280	7⅝	do
350	do	do	do	1,950	5 Sp			do
351	Marvindale	Bradford Wood Products Co.	Valley	1,620	Dr	60±	6	?
	Sergeant Township							
352	Clermont	Clermont Clay Products Co.	Plateau		Dr	247	6	Gray sandstone
	Norwich Township							
353	Crosby	Harriman Chemical Co.	Valley	1,500	2 Dr	261, 300	6	Gravel

[1] Dr, drilled well; Sp, spring.

[2] A, air lift; F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated; T, turbine pump.

[3] C, cooling or condensing; D, domestic; In, industrial; N, none; O, flooding wells for oil recovery; P, public supply; S, stock; Sp, swimming pool; W, washing automobiles.

[4] See remarks column.

[5] Altitudes from Olean Petroleum Co.

[6] Altitudes from Mt. Jewett Water Co.

in McKean County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pocono or Catskill	24	—150±	A	15±	P	Well No. 4.
do	46	—100±	A	15±	P	Well No. 5.
do	36	—90±	A	15±	P	Well No. 6.
Pocono	--------	--------	F	60	P	Aggregate discharge of all five springs estimated September 7, 1935. Temp. 48° F. See analysis.
Pleistocene or Catskill	?	—20±	S	25	In	
Pottsville or Pocono	?	— ?	N	--------	N	Plant shut down. Continued drilling and casing deeper for soft water—supply inadequate.
Pleistocene	261, 300	— ?	N	50±	N	

POTTER COUNTY

[Area, 1,071 square miles. Population, 17,489]

GEOGRAPHY

Potter County lies in the north-central part of the area and borders New York State on the north. It is sparsely populated, having only about 16 inhabitants per square mile, most of whom live in the northern half of the county. Most of the county is forested, and the southern half is practically a wilderness noted as an excellent hunting region. Only 34.2 percent of the total land area is devoted to farming. Coudersport, the county seat and largest borough has 2,740 inhabitants, and Galeton is next with 2,200. Shingle House and Austin are the only other boroughs having more than 1,000 inhabitants. An important discovery of deep-seated natural gas in Potter County was made in 1931. There are also several shallow oil and gas fields in the northwestern part of the county. Potter County has very little coal as compared to the other counties in the area. According to the Federal census of 1929, there were 32 manufacturing establishments in the county whose products were valued at a total of $6,966,755.

The topography in Potter County differs somewhat from that of McKean County in that the high plateau surface is broken by several anticlinal valleys, leaving six ranges of synclinal highlands trending northeast. Only the northern part of the county has been surveyed topographically, so that the highest and lowest points are not definitely known. In the northern part, several hills stand 2,560 feet above sea level, including Cobb Hill in Allegany Township, Lyon Hill, and Denton Hill in Sweden Township, and an unnamed hill in Ulysses Township. Many other hills in Potter County stand above an altitude of 2,500 feet. The lowest point in the county is either where Pine Creek crosses the Tioga County line or where the First Fork of Sinnemahoning Creek crosses the Cameron County line, and is probably less than 1,300 feet above sea level. The maximum relief, therefore, may be at least 1,260 feet. The greatest local relief is found where the main streams cut through the synclinal ridges.

Potter County lies in three major drainage basins. A flat-topped hill in Ulysess Township 1.7 miles south of Gold marks the junction of the three basins. Part of the precipitation that falls on this hill drains northward into the Genesee River, and thence to the St. Lawrence River; part drains west into the Ohio River and thence to the Gulf of Mexico; and part drains east into the Susquehanna River and thence to the Atlantic Ocean. The Genesee River drains a small area in the north-central part of the county, the Allegheny River drains the northwestern part, tributaries of the West Branch of the Susquehanna River drain most of the southern and eastern parts, and a small area at the northeast corner is drained by the Cowanesque River, a tributary of the North Branch of the Susquehanna River.

No description of Potter County would be complete without some mention of the "Coudersport Ice Mine," near the village of Sweden Valley. It is said to have been discovered in 1894 by some people who dug a shaft on the hillside in search of silver. Instead of silver they encountered layers of ice in the rocks, and abandoned the partly completed shaft. The next spring, and every succeeding spring, ice

formed in the shaft, remained throughout much of the summer, but gradually melted away as winter approached. The ice mine has been surrounded by a tall wooden fence with a locked door, and guides now take people into the enclosure and explain the so-called mystery for a small admission fee. Many other similar accumulations of ice are known in the United States and in Europe, and the mode of their formation has long been known. It is strange, therefore, that the guides and descriptive booklets almost invariably state that the phenomenon "has long been a puzzle to scientists."

The ice mine is located on the north side of a heavily forested hill, where the ground remains damp, shady, and free from wind and sunlight. There is evidence that the rocks underlying the hillside are greatly jointed with a considerable number of cracks and fissures, and perhaps are covered with loosely piled rocks that have come down from the hills above. The most generally accepted theory of the formation of the ice, as noted by Balch,[74] is that the crevices in the rocks store up a large amount of cold dry winter air, which being heavier than warm air, sinks into the cracks. No ice forms during the winter in the shaft, because all water is then frozen on the outside. In the spring, however, water from the rain and melting snow trickle into the crevices and, meeting the cold dry air within, freezes to ice. The ice continues to form as long as water and the stored supply of cold air lasts, but as summer advances the ice begins to melt very slowly and is generally all melted by November. There is often alternate freezing and thawing of the ice during part of the summer.

GEOLOGY

The consolidated rocks exposed in Potter County range in age from the Chemung formation of Upper Devonian age (oldest) to the Pottsville formation of Pennsylvanian age. The older rocks crop out along anticlinal valleys trending northeast, and the youngest rocks cap the plateau along six synclinal ranges of highlands. The errors in the mapping of the Pottsville formation on plate 1 are noted on page 90.

The northeast corner of Potter County was covered by the Wisconsin glacier, and probably in part by the Illinoian glacier, whose southern terminus extended slightly beyond that of the Wisconsin in the east-central part of the county (plate 1). The drift mantle appears to be much thinner in Potter County than in Bradford County, which is substantiated by the depths to bedrock in the wells in interstream areas (plate 2). The main valleys in the northern half of the county were occupied by glacial lakes during the Pleistocene and now contain thick lake deposits similar to those in McKean and Tioga Counties. The history of the formation of these lakes and their deposits and the general character and water-yielding capacity of the deposits is given in the first part of this report, and their areal extent is shown in plate 2. Non-glacial stream deposits in the southern half of the county are described on page 96.

In plate 2 are shown 6 glacial spillways through which water from Glacial Lake Genesee might have spilled over into the Allegheny and Susquehanna drainage systems during different stages of the lake.

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[74] Balch, E. S., The Coudersport Ice Mine: Am. Ph. Soc. Proc., vol. 60, no. 4, pp. 555-558, 1921.

This differs somewhat from the earlier map of Fairchild[75] in which 3 of these spillways are shown, and in which a fourth spillway not recognized by the writer is also shown.

The geologic structure in Potter County, as shown in plate 4, comprises six major anticlines, six intervening major synclines, and several folds of local extent all trending about N.55°E. As summarized by Cathcart[76] "In general, regional plunge is southwest, intensity of folding decreases from southeast to northeast, and folds are asymmetric with slightly steepened southeast limbs. The most striking quality of the structures is their parallelism. The Smethport [anticline] in this area is a relatively broad flat fold; all others are well defined features having maximum dips of 5 or 6 degrees."

GROUND WATER

The glacial lake deposits shown in plate 2 are potentially the most productive sources of ground water in Potter County, but they have not been utilized extensively as they have in McKean County. The most productive sands and gravels are in the valley of Oswayo Creek and Allegheny River. Large supplies from properly constructed wells have been sought only in the Allegheny Valley at Roulette, where well 398 yields 465 gallons a minute. The water in these deposits is generally of good quality but locally as in parts of McKean County, it contains considerable iron. Along the Allegheny River between Roulette and Coudersport many of the wells are cased through the iron-bearing water in the gravel and obtain somewhat better water from the underlying Chemung formation even though the gravels are far more productive than the bedrock.

The Chemung and to a lesser extent the Catskill or Cattaraugus supply most of the wells ending in bedrock. Yields of 40 to 50 gallons a minute are generally obtainable from these rocks, and a few wells in the Chemung yield as much as 200 gallons a minute. The Pocono supplies only a few camps and homes on the plateaus, and the Pottsville apparently is not utilized at all.

In the northern half of the county considerable ground water is used by different industries, including dairies, ice plants, chemical plants, and tanneries. Bottled water obtained from flowing well 379 is shipped by the Harrison Valley Mineral Water Company. Considerable ground water is used also for public supply in the northern part of the county. In the southern half of the county ground water is used only at camps and farms, except at Austin where some is used for public supply (see below). Some dug wells are still in use, particularly along the valleys in the southern half of the county. Springs or drilled wells appear to supply most of the homes in the northern half. Several moderately large springs are noted below in the descriptions of the public supplies of Coudersport and Genesee.

Records were obtained of 8 flowing wells in Potter County, and there are numerous others in the vicinity of Harrison Valley and possibly in a few other localities (plate 2). Most of the flows are small, but well 379 at Harrison Valley is reported to flow 80 gallons a minute,

[75] Fairchild, H. L., Glacial Genesee lakes: Geol. Soc. America Bull., vol. 7, pl. 19, 1896.

[76] Cathcart, S. H., Gas and oil in Potter County, Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 106, p. 20, Feb. 1, 1934.

and the water is reported to rise 25 feet above the land surface when the casing is extended upward. In the vicinity of Ellisburg flows of about 50 gallons a minute were observed issuing from between the second and outer casings of deep (5,000 feet) gas wells, the water coming from a depth of about 500 feet. Several houses in the village are supplied with water under pressure obtained from the outer casing of an old gas well. Flowing wells at Lewisville and Germania are on the axes of anticlines.

The weekly water levels in an observation well at Conrad (no. 417) are shown in figure 6. A photograph of this well is shown in plate 8A.

Analyses of 5 samples of water from different geologic formations in Potter County are given below. The general quality of water to be expected from the different geological formations is summarized elsewhere. Iron in objectionable amounts is found in some waters in the Pleistocene deposits, particularly in the Allegheny Valley as noted above, and in some of the Pocono waters. Very little trouble from iron was reported in any Chemung or Catskill waters, though some of these contain hydrogen sulphide. Salt water, so common in many wells in the Chemung of Bradford and Tioga Counties, was not reported in any of the wells drilled primarily for water in Potter County, but is encountered at considerable depth in oil and gas wells, as in well 420 at Germania. The waters analyzed are soft, and very few hard waters were reported. In general the ground waters in Potter County are entirely satisfactory for most purposes, except for those containing considerable iron.

Analyses of ground waters from Potter County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in plate 2]

Number	364	372	381	405	411
Geologic horizon	Pleistocene	Pleistocene	Cattaraugus	Pocono	Pocono
Silica (SiO_2)	—	6.8	—	—	—
Iron (Fe)	8.1	.04	0.13	1.7	0.25
Calcium (Ca)	—	11	23	—	—
Magnesium (Mg)	—	4.6	8.5	—	—
Sodium and potassium (Na+K)	—	Na 2.4, K .9	16	—	—
Bicarbonate (HCO_3)	28	47	139	30	12
Sulphate (SO_4)	12	8.9	8	6	5
Chloride (Cl)	9.0	1.6	3.0	9.0	.6
Nitrate (NO_3)	1.5	3.0	1.6	4.7	2.1
Total dissolved solids	[1]57	61	129	[1]54	[1]21
Total hardness as $CaCO_3$	45	46	92	52	15
Date of collection, 1935	Aug. 26	Aug. 28	Aug. 28	Aug. 29	Aug. 29

[1] Estimated.

PUBLIC SUPPLIES

Of the 7 public water supplies in Potter County, 6 are derived exclusively from ground water, and one (Galeton) is derived from ground and surface water.

Austin (population 1,116) is supplied by the Austin Borough Water Works. The main supply comes from 3 hillside springs in the bor-

ough that issue from shale. Their aggregate yield generally exceeds the average daily consumption, which is 150,000 gallons a day. An auxiliary supply is obtainable from one drilled well which yields 80 gallons a minute. There are four other wells that are no longer in use (see well 416). The water is pumped directly into the mains by either of two double-acting force pumps, powered by natural gas engines. The excess water accumulates in a 220,000-gallon concrete reservoir located on a hill east of the main part of the borough. The maximum pressure in the distributing system is 125 pounds per square inch. There are 30 fire hydrants. All water is chlorinated at the pump station, and is used entirely for domestic purposes.

Coudersport (population 2,740) is supplied by the Consolidated Water Company. The main supply comes from 7 springs, and in emergencies another spring and one drilled well are available. The two Reese Hollow Springs issue from gravel and are reported to yield a total of 2 million gallons a day (nearly 1,400 gallons a minute) during 8 months of the year. The Cobb Hollow Spring issues from gravel and is reported to flow about 150 gallons a minute. The Niles Hill Spring, also in gravel, is reported to yield 100 gallons a minute. The two Coralynn Springs issue from shale and have a combined flow of 50 gallons a minute. All springs but the Niles Hill Spring flow into a 600,000-gallon reservoir, from which water is distributed by gravity at pressures ranging from 40 to 50 pounds per square inch. The Niles Hill Spring flows into a 2-million-gallon fire reservoir, which supplies 63 fire hydrants at a pressure of 90 pounds per square inch. The Emergency Spring issues from gravel, and flows 200 gallons a minute into a 50,000-gallon reservoir. When additional water is needed, it is pumped directly into the mains from this low-lying reservoir. If more water is needed, it is pumped directly into the mains by the turbine pump in well 399, which yields 200 gallons a minute from the Chemung formation. The average daily consumption is 300,000 gallons, of which about 200,000 gallons is used for domestic purposes, 80,000 gallons is used by manufacturers, and 20,000 gallons is used by a railroad. The water from the Emergency Spring is chlorinated, but that from other springs and well is not treated.

Galeton (population 2,200) is supplied by the Galeton-Eldred Water Company, which also supplies Eldred in McKean County. The main part of the borough (including one silk mill) is supplied from 6 small streams: Beech Flat Brook, 2 miles west of the borough; the Right and Left Branches of Wetmore Run, 3 miles west; and Martin Hollow, near West Pike. The water flows by gravity into a 135,000-gallon reservoir at Wetmore Run, a 165,000-gallon reservoir at Johns Hollow, and a 120,000-gallon reservoir on a hill north of the borough, and is distributed by gravity at an average pressure of 72 pounds per square inch. The fire hydrants are also connected to this system. A milk condensary is supplied entirely from the Hammond Spring, which issues from shale in the south part of the borough. The Community Building and the brewery are supplied entirely from two springs that issue from shale in Bougher Hollow, south of the borough. The average daily consumption from all sources is 125,000 gallons.

Genesee is supplied by the Genesee Citizens Water Company from 2 springs (no. 372) near Hickox, which have a combined yield of about

100 gallons a minute from gravel. The springs discharge into 2 nearby concrete reservoirs holding a total of about 13,000 gallons, from which the water is distributed by gravity at an average pressure of about 45 pounds per square inch. About 80 families are supplied. The water is not treated and is very soft as shown by analysis 372. Another spring that issues from gravel just east of Genesee furnishes water to 10 fire hydrants, at a pressure of 75 pounds per square inch.

Lewisville (Ulysses P. O., population 514) is supplied by the privately-owned Lewisville Water Company. The distribution is divided into 2 separate systems, a low-pressure system and a high-pressure system. The low-pressure system is supplied from one spring that issues from glacial drift and flows about 20 gallons a minute. The water is stored in a 70,000-gallon reservoir and is distributed by gravity. The high pressure system is supplied from one flowing drilled well (no. 381) which flows 21 gallons a minute. In order to obtain additional water, the well is pumped part of the time at a rate of 40 gallons a minute. Water from the well is pumped directly into the mains of the high-pressure system, and the excess water is stored in a 32,000-gallon concrete reservoir. The pressure in both systems is about 15 pounds per square inch. About 150 families are supplied, all water being used for domestic purposes. The spring water is not treated, but chloride of lime is added to the well water. Analysis 381 of the well water indicates a good average water.

Roulette is supplied by the Roulette Water Company from 7 springs that issue from sandstone along Lanninger Creek. Six of the springs are located near the headwaters of the creek, 2½ miles south of Roulette, and discharge into a reservoir formed by a dam. The water flows 1½ miles north to the distributing reservoir, into which the other spring also flows. The water is distributed by gravity at pressures ranging from 40 to 60 pounds per square inch. Water is furnished to 200 people, and some water is also furnished to the Gray Chemical Company which, however, is supplied mainly from well 398. The spring water is not treated.

Shingle House (population 1,380) is supplied by the privately owned Shingle House Water Company, from 9 springs and 8 drilled wells. The 9 springs issue from bedrock in the hills about 1½ miles south of the borough and the combined discharge of 6 of the springs flows into the 152,000-gallon concrete distributing reservoir on a hill along the southern boundary of the borough. Four of the drilled wells are in the borough and each yields 60 gallons a minute from gravel. Water from these wells and the remaining 3 springs is pumped directly into the mains. The two wells in the eastern part of the borough (nos. 356, 357) are used most of the time, but the two wells in the western part of the borough (nos. 354, 355) are seldom needed. Four other wells (no. 359) in the Chemung formation located near the reservoir are equipped with pump jacks and cables connected to one engine, and yield about 25 gallons a minute each. These wells are pumped only when additional water is needed, and discharge into the distributting reservoir. The service pressures range from 30 to 40 pounds per square inch. The 42 fire hydrants are evidently supplied from a different reservoir, at a pressure of 70 pounds per square inch. Water is supplied to 225 families, a cheese factory, and a hosiery mill. None of the water is treated.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Sharon Township							
354	Shingle House	Shingle House Water Co.	Valley	1,480	Dr	130	6¼	Gravel
355	do	do	do	1,480	Dr	85	6¼	do
356	do	do	do	1,480	Dr	131	6¼	do
357	do	do	do	1,480	Dr	65	6¼	do
358	do	Shoe Last Factory	do	1,480	Dr	40	4	White gravel
359	On south borough line of Shingle House	Shingle House Water Co.	Hillside	1,650	4 Dr	226–302	6¼	
360	1.4 miles southeast of Shingle House	Ellery Washburn	Slope	1,540	Dr	70	4	Gray sandstone
361	Sharon Center	Lee band	Valley	1,520	Dr	47	4	Fine gravel
362	0.8 mile south of Sharon Center	Fred McAllister	Canyon	1,620	Dr	78±	4	Gray sandstone
363	Millport	Millport Cheese Co.	Valley	1,540	Dr	25	4	Gravel
364	do	Dairymen's League Cooperative Ass'n.	do	1,540	Dr	36	8	do
365	do	Vernon Cook	do	1,540	Dr	65	4	do
366	1.3 miles northeast of Millport	Clinton Smith	Hillside	1,690	Dr	97	5	do
	Oswayo Township							
367	2.1 miles northeast of Millport	Earl Olds	Canyon	1,680	Dr	76	4	do
368	2 miles northwest of Oswayo	William Woodard	Valley	1,800	Dr	56	4	do
369	Oswayo	Dr. Cummings	do	1,710	Dr	69	4	Gray sandstone
370	do	Clarence Head	do	1,710	Dr	60±	4	Coarse sand
	Genesee Township							
371	Ellisburg	Cobb Estate	Hillside	1,900	Dr	146	6	Dark sandstone
372	0.5 mile east of Hickox	Genesee Citizens Water Co.	do	1,760	Sp			Gravel

in Potter County

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	130	—15	P	60	P	Well No. 1, station 2. Water reported good, open finish.
do	85	—18	P	60	P	Well No. 2, station 2. Water reported good, open finish.
do	131	—30	P	60	P	Station 2, open finish.
do	65	—30	P	60	P	Station 2, open finish.
do	40	—24	N	--------	N	Plant burned. Large yield reported. Gravel overlain by clay, sand, and boulders.
Chemung	60–86	—100	P	25	P	Station 3. Equipped with pump-jacks and cables connected to one engine, each yields 25 gallons a minute.
do	18	—58	N	5	N	Driller reported natural gas issued from well, from nearby leaking gas wells, sufficient to supply house.
Pleistocene	47	—15±	H	10	D	Open finish.
Chemung	62	—63±	H	5±	D	Hardpan above bedrock.
Pleistocene	25	—4	C	10±	C, I	Open finish. Water contains iron.
do	36	—4	S	12	C, I	Open finish. Temp. 51° F., water contains considerable iron. See analysis. Abandoned 300-foot well very weak, cased 150 feet to bedrock.
do	65	—4	H	20±	D	Water contains iron. Sand and gravel, 45 feet, clay 20 feet, gravel below 65 feet.
do	50	—85±	N	15±	N	Caved due to insufficient casing, no bedrock encountered.
do	76	—56	H	5	D	Clay, sand and gravel overlies water-bearing gravel.
do	55	—25±	H	10	D	
Cattaraugus	40	—6	P	5+	D	Water-bearing sand and gravel cased, some clay layers.
Pleistocene	60	—6±	S	10±	D	
Chemung	12	—63	P	17	I	Water used for drilling gas well.
Pleistocene	--------	--------	F	100±	P	Water issues in two places. Reported low in 1930. Temp. 48° F. Water soft. See analysis.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Bingham Township							
373	0.7 mile north of North Bingham	John Hubbard	Hilltop	2,180	Dr	199	6¼	Red sandstone
374	North Bingham	Thomas Telbert	Upland	2,140	Dr	116	5	Light sandstone
375	Bingham Station	P. H. Miller	do	2,180	Dr	100	6¼	Red sandstone
	Harrison Township							
376	0.6 mile southwest of Whites Corners	Edward Floellen	Hillside	2,120	Dr	116	4	Gray sandstone
377	1.8 miles northeast of Mills	James English	Ridge	2,140	Dr	216	5⅝	Red sandstone
378	Mills	G. F. Pride	Valley	1,740	Dr	120	4	Hard gray sandstone
379	Harrison Valley	Harrison Valley Mineral Water Co.	do	1,610	Dr	200	6±	Sandstone
	Ulysses Township							
380	Lewisville (Ulysses Post Office)	Galeton Dairy Products Co.	do	2,060	Dr	92	6¼	Red shale
381	do	Lewisville Water Co.	Slope	2,100	Dr	126	6	Gray sandstone
382	1.7 miles southwest of Lewisville	F. L. Brown	Hillside	2,060	Dr	117	6¼	
383	0.8 mile south of Lewisville	Andrew Gridley	Upland	2,260	Dr	117	6¼	
384	1.6 miles southeast of Newfield	Mrs. Coburn	do	2,280	Dr	100±	6	Gray sandstone
385	Gold	Fred Clark	Valley	2,120	Dr	120±	5	do
386	Walton Station	S. J. Brendel	do	1,580	Dr	71	6¼	Gray shale
	Allegany Township							
387	0.4 mile north of Raymond	Frank Davis	Hillside	2,320	Dr	116	5	Gray sandstone
388	0.7 mile south southeast of Raymond	Millie Kidney	Upland	2,380	Dr	160	5	Hard sandstone
389	0.1 mile north of Lewis Corner	Theodore Cobb	Hillside	2,100	Dr	221	6	Gray sandstone
	Hebron Township							
390	1.8 miles east southeast of Hebron Center	Harvey Fulton	Canyon	2,020	Dr	80	6⅝	

in Potter County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Cattaraugus	16	—	?	--------	D, S	
do	40±	—	H	5±	D, S	
do	24½	—45	P	--------	D, S	Temp. reported 49° F.
do	20	—66±	H	10±	D, S	Bedrock at depth of 3 feet.
do	12	—60±	P	10±	D	
Chemung	60	+5	P	10±	D	Flows. Drawdown 3 feet pumping about 10 gallons a minute. Another flowing well across street. 60 feet of clay and gravel cased.
do	50	+25	F	80	B, D	Flows 80 gallons a minute. Supplies 3 houses and water bottling company. Water contains hydrogen sulphide. Nearly all wells in Harrison Valley reported to flow.
Cattaraugus	32½	+	F	13	N	Flows about ¼ gallon a minute. Plant abandoned.
do	30	+2.5	F, P	40+	P	Flows 21 gallons a minute, pumps 40 with 4 feet drawdown. Temp. 48° F. See analysis.
do	18	—60	P	15±	D, S	
do	45	—68	P	14±	D	
do	40	—	H	5±	D	Sand and gravel cased.
do	70+	—	H	--------	D	About 70 feet of sand and gravel cased.
do	7	—8	H	5±	D	
Pocono	50	—60±	H	5±	D	Gravel and clay cased.
Pocono or Catskill	30	—150	H	3±	D	
Catskill	20	—75±	P	20	I	Water used for drilling gas well. Large drawdown reported.
Catskill or Chemung	17	—	H	--------	D	

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Hebron Township—Continued							
391	2 miles northwest of Colesburg	Coyle Farm	Hillside	2,300±	Dr	388	6	Red shale
392	1.3 miles south southeast of Hebron Center	Amos Sturdevant	Canyon	1,930	Dr	35	4	Brown sandstone
393	1 mile southwest of middle of Oswayo	Stewart Gleason	Valley	1,660	Dr	62	4	Fine sand
394	0.8 mile west of Conesville	George Holcomb	do	1,600	Dr	50	5	Fine gravel
395	0.9 mile northeast of Hebron	Randolph Burdick	Canyon	2,140	Dr	140	4	Gray sandstone
396	1.5 miles south of Hebron	Roy Clark	Upland	2,180	Dr	148	5⅝	Red sandstone
397	1.6 miles south southwest of Hebron	W. W. Thompson	do	2,220	Dr	40	5⅝	Gray sandstone
	Roulette Township							
398	Roulette	Gray Chemical Co.	Valley	1,540	Dr	126	10	Gravel
	Eulalia Township							
399	North end of Coudersport	Consolidated Water Co.	do	1,680	Dr	195	8-6	Sandstone
400	do	American Silver Truss Corp.	do	1,680	Dr	210	6	Gray sandstone
401	Southeast corner of Coudersport	Elk Tanning Co.	do	1,640	Dr	210	8-6	do
402	South end of Coudersport	Abbotts Dairies, Inc.	do	1,640	Dr	196	8	do
403	1.8 miles southeast of middle of Coudersport	Kenneth Berrie	Ridge	2,450	Dr	277	6	Hard white sandstone
	Sweden Township							
404	0.3 mile west southwest of Sweden Valley	William Shear	Hillside	1,860	Dr	116	5	Gray sandstone
405	Roosevelt Highway on Denton Hill	S. H. Worthington	Ridge	2,424	Dr	130±	6	Sandstone
	Pike Township							
406	Galeton	Galeton Silk Mills, Inc.	Valley	------	Dr	67	6	Red sandstone
407	do	Oxford Milk Products Co.	do	------	Dr	158	8	Gray sandstone

in Potter County—Continued

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	5½	—350±	P	7½	I	Water used for drilling gas well. Large drawdown.
do	12	—20±	H	5	D	
Pleistocene	62	—20	H	10±	D	Open-end well, pumps sand, water in overlying gravel contains iron.
do	50	—40±	H	4	D	Open-end well.
Catskill or Chemung	16	—125±	P	2±	S	
Catskill	14	—118±	P	--------	D, S	
do	16	—12	H	5±	D	
Pleistocene	90	—22	T	465	C, I	Open-end well. Gravel from 90 to 126 feet holds without casing. Drawdown 58 feet. Water contains iron. Have 6 other wells 110 to 155 feet deep in gravel, equipped with air lift, seldom used.
Chemung	100	—7	T	200	P	100 feet of sand and gravel cased. Drawdown 58 feet. Water reported good, contains hydrogen sulphide.
do	80	—16	H	--------	N	Water contains hydrogen sulphide, but is of good quality.
do	180	—18±	P	50±	I	180 feet of sand and gravel cased, because water in gravel contains iron.
do	102	—26	P	50	C	102 feet gravel and sand cased, water in gravel at 70 feet will flow above surface, but water contains iron. Water in sandstone good but contains hydrogen sulphide.
Pocono or Catskill	9	—217	?	0.1±	D	Very weak.
Catskill	30±	—100±	H	5±	D	
Pocono	--------	—	H	--------	D	Temp. 46° F., some iron. See analysis.
Catskill	11	—6	S	40	I	Drawdown 12 feet. Seldom used, as water causes boiler to foam.
do	12	—9±	P	20	I	Water satisfactory for boiler.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	West Branch Township							
408	1.3 miles south of Galeton	Frank Hurd	Valley		Dr	63	6	Gray sandstone
409	West Branch	Mrs. Mae Conable	do		Dr	96	6	Red sandstone
410	1.2 miles south southwest of Lyman Run.	Segar Prindle Manufacturing Co.	Canyon		Dr	168	6¼	do
411	Cherry Springs	State Emergency Relief Administration	Upland		Dr	169	6	Gray sandy shale
	Keating Township							
412	4 miles north northwest of middle of Austin	Civilian Conservation Corps, Camp No. P-146	Hillside		Dr	200	6	Gray shale
413	Keating Summit	Elmer Sebring	High saddle		Dr	50	5	Red sandy shale
414	2.3 miles southeast of Keating Summit	Joseph Rydesky	Upland slope		Dr	175	4	Gray sandstone
	Portage Township							
415	2.3 miles southeast of Keating Summit	O. M. Stukey	do		Dr	175	4	do
416	Austin	Austin Borough Water Co.	Valley		Dr	230	8	do
	East Fork District of Eulalia Township							
417	Conrad	H. B. Walker	do		Du	13.5	24	Gravel
	Abbott Township							
418	1.4 miles east northeast of Cartee Camp	Frank Sykora	Upland		Dr	297	6¼	Red sandy shale
419	Germania	Mrs. Rena Campbell	Valley		Dr	71	6¼	Gray sandstone
420	do	Germania Village	do		Dr	241	8	do
	Stewardson Township							
421	1.5 miles north of Cross Fork		do		Dr	68	6	Red sandstone

[1] C, centrifugal pump; F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated; T, turbine.

[2] B, bottling; C, cooling or condensing; D, domestic; I, industrial; N, none; S, stock.

in Potter County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	24±	—35±	H	2±	D	
do		+ to —19	H	5±	D	Flows a small quantity in the winter.
do	45±	+6	P	8±	D, I	Flows about 2 gallons a minute. Sand and gravel cased.
Pocono	25	—12±	P	10+	D	Supplies camp. Reported drawdown 20 feet pumping 40 gallons a minute. Temp. 48° F. See analysis.
Catskill	88½	—53	P	10	D	Some water at depths of 50, 85, 135, 163, 170, and 176-188 feet, main supply at 105 feet.
do	36	—30	H	10	D	
Pocono	46	—90±	P	2±	D, S	A nearby well 325 feet deep yielded only 9 gallons an hour.
do	31	—99	P	3+	D, S	Reported drawdown 40 feet after 2 hours pumping 10 gallons a minute.
Chemung	30	—20	T	80	P	Drawdown 17 feet after 12 hours. Water contains some hydrogen sulphide and iron. Have 4 wells 80 feet deep, aggregate yield by air lift 50 gallons a minute. One flowing well 1,000 feet north stops flowing when well 416 pumped.
Recent	13.5	—2.3 to —5.8	N		N	Observation well. Water level measured weekly by H. B. Walker or Harold Williams since August, 1935. See plate 8A and fig. 6.
Catskill	21	—94	P	2	D, S	Maximum yield.
Chemung	9	+2	F	1±	D	Flows about 1 gallon a minute. Reported drawdown 58 feet pumping 30 gallons a minute.
do	14	+1.5	F	5±	D	Oil test 2,300 feet deep, plugged at 241 feet. Salt water at 510 feet, fresh at 90 and 218. Water contains hydrogen sulphide.
Catskill	32	—45±	H	4	D	

SULLIVAN COUNTY

[Area, 458 square miles. Population, 7,499]

GEOGRAPHY

Sullivan County occupies the southeast corner of the area described in this report. Next to Cameron County, it is the smallest county in the area. It is very sparsely populated, and like Potter County has only about 16 inhabitants per square mile. Dushore, the largest borough, has only 715 inhabitants. The other three boroughs, Eagles Mere, Forksville, and Laporte, all have less than 300. Much of the county is mountainous and forested, and only about 28 percent of the total land area is devoted to agriculture. Sullivan County is a favorite hunting, fishing, and recreation region, and abounds in small lakes, the best known of which is Eagles Mere Lake. Some semi-anthracite has been mined in the Bernice coal basin. These mines were inoperative when visited in 1935, but it was planned to reopen them. Sullivan County ranks last among the 8 counties in manufacturing. According to the Federal census of 1929, there were 14 manufacturing establishments in the county whose total annual output amounted to only $765,004.

The southern boundary of the county practically coincides with the bold escarpment known as the Allegheny Front. Thus most of the county is a high remnant of the Appalachian plateau, deeply dissected by Loyalsock and Muncy Creeks. An unnamed peak on North Mountain in Davidson Township stands at an altitude of 2,593 feet, and is the highest known point in that part of north-central Pennsylvania for which topographic maps are available. Several other peaks on North Mountain have altitudes of more than 2,500 feet, and considerable areas lie above 2,400 feet. Loyalsock Creek crosses the Lycoming County line at an altitude of about 770 feet, the lowest point in the county. The maximum relief is therefore about 1,823 feet. The greatest local relief is found along Loyalsock and Muncy Creeks, which flow through narrow gorges 1,200 to 1,400 feet deep. These two creeks drain the larger part of the county, and small areas at the east and southeast are drained by tributaries of the North Branch of the Susquehanna River.

GEOLOGY

The rock formations exposed in Sullivan County range in age from the Chemung formation of Upper Devonian age (oldest) to the Pottsville formation of the Pennsylvanian age. The Chemung formation is exposed by the Wilmot anticline in the north-central part of the county, and just reaches the southern boundary of the county along Muncy Creek. The Catskill rocks crop out along the escarpments of the plateau, and the Pocono formation caps the plateau. The Pottsville is preserved in the Bernice basin and in two smaller areas. All of Sullivan County except the highest parts of North Mountain and Allegheny Ridge was covered by the Wisconsin glacier, which has left abundant evidence of its former presence in the form of numerous small glacial lakes, marshes, and moraines such as are shown in plate 5A. Deposits of glacial outwash are found along Loyalsock and Muncy Creeks and along a few smaller streams as shown in plate 2. The geologic structure in Sullivan County is shown in plate 4.

GROUND WATER

The glacial outwash gravels along Loyalsock and Muncy Creeks are potentially the most productive water-bearing materials in the county, but to date very few large supplies have been sought from these materials. One well (no. 422) at Wheelerville had a reported yield of 100 gallons a minute from gravel. Most wells in the county tap the Catskill and Pocono. Yields of 125 to 300 gallons a minute are obtained from the Catskill at Dushore (wells 427, 429) and one well in the Pocono at Laporte is reported to yield 100 gallons a minute.

Dug wells are still used predominately in many parts of the county, including many communities such as Forksville, Hillsgrove, Millview, Colley, and Lopez. In the main valleys some driven wells are also used. Numerous small springs such as spring 434 are also used for domestic supply. Drilled wells probably supply most of the homes on the plateau, and are used at most of the newer installations in the valleys.

Wells 427 and 428 in Dushore are the only industrial wells observed in use in the county. Drilled wells are used for public water supply in Dushore and Laporte, as noted below.

Well 441 at Eagles Mere Park is the only flowing well observed in the county. Although this well is in bedrock, the confining bed is probably the thick layer of glacial drift which covers the bedrock at this locality. There appear to be no areas where flowing wells can be obtained with certainty.

The weekly water levels in an observation well near Millview (no. 425) are shown graphically in figure 6.

Analyses of 4 samples of water from 4 of the water-bearing formations in Sullivan County are given below. These analyses show waters

Analyses of ground waters from Sullivan County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in pl. 2]

Number	427	433	438	448
Geologic horizon	Catskill	Pottsville	Pocono	Pleistocene
Silica (SiO_2)	—	7.8	—	—
Iron (Fe)	0.12	.79	0.10	0.10
Calcium (Ca)	34	24	—	35
Magnesium (Mg)	4.7	4.9	—	5.4
Sodium and potassium (Na+K)	23	Na 9.8 K 3.2	—	9
Bicarbonate (HCO_3)	132	53	43	133
Sulphate (SO_4)	20	41	3	12
Chloride (Cl)	16	8.0	1.1	4.0
Nitrate (NO_3)	3.8	5.9	1.5	3.7
Total dissolved solids	167	135	[1]44	135
Total hardness as $CaCO_3$	104	80	32	110
Date of collection, 1935	Aug. 7	Aug. 7	Aug. 7	Aug. 7

[1] Estimated.

of low to moderate hardness and concentration. Iron in undesirable concentration was reported in waters from several wells in the Pocono formation. No salt walter was reported in any of the wells, and is not likely to be encountered in any part of the county except possibly from deep wells that tap the Chemung formation. The general quality of water to be expected from the different formations is summarized on pages 74, 75.

PUBLIC SUPPLIES

Dushore, Eagles Mere, and Laporte are the only boroughs in the county that have public water supplies. Laporte uses ground water exclusively, Dushore uses both ground and surface water, and Eagles Mere now uses surface water exclusively.

Dushore (population 715) is supplied by the Dushore Water Company. The main supply comes from Paine Run, a small stream east of the borough, on which there is a dam that impounds 700,000 gallons. When the stream is low, additional water is pumped into the reservoir from a drilled well (no. 429) located just above the reservoir. The well is equipped with a turbine and yields 125 gallons a minute. The water is distributed by gravity and is chlorinated as it leaves the reservoir. The average daily consumption is 40,000 gallons, all of which is used for domestic purposes.

Eagles Mere is supplied by the Eagles Mere Water Company. Although the permanent population served by the company is small, the summer population amounts to several thousand. All water used is pumped from Eagles Mere Lake, and is filtered, aerated, and chlorinated. In 1929 the average daily consumption was about 200,000 gallons. At one time 3 drilled wells, numbers 444 and 445, were used but the supply proved inadequate. Following is a composite log of two of the wells.

Log of well of Eagles Mere Water Co. at Eagles Mere

[No. 445. Authority, E. S. Chase, Engineer, Williamsport Water Co.]

	Depth (feet)		Depth (feet)
Dirt	0–15	Sandstone, gray (water at 168)	165–181
Sandstone, gray	15–40	Sandstone, white	181–193
Sandstone, white (water at 70)	40–75	Shale, red	193–199
Fire clay	75–82	Sandstone, gray	199–205
Shale, red (water at 160)	82–165		

Laporte (population 163) is supplied by the Makoma Spring Water Company. The main supply comes from a spring, which discharges from 20 to 200 gallons a minute into a 16,000-gallon reservoir, whence the water is pumped to an 80,000-gallon concrete reservoir on a high hill in the borough. Another small spring (no. 437) flows a small amount. Additional water was formerly pumped from well 436 located near the distributing reservoir. When the plant was visited in July, 1935, however, well 435 had just been completed, and was being con-

nected so that the turbine pump could pump water directly into the mains at a rate of 100 gallons a minute. As soon as the connection could be made, it was planned to use well 436 only in emergencies. The water is distributed by gravity at pressures ranging from 33 to 100 pounds per square inch. The average daily consumption is 7,000 gallons. The water is not treated and is reported to be very soft.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Fox Township							
422	Wheelerville	Dairymen's League Cooperative Ass'n, Inc.	Upland Valley		Dr	60±	6	Gravel
	Elkland Township							
423	0.5 mile northwest of Campbellville	Ralph Hugo	Ridge		Dr	105	6	Red shale
	Forks Township							
424	1.3 miles southwest of Overton	Wallace Huttouslein	Hillside		Dr	158	6	do
425	0.2 mile west southwest of Millview	Carl D. Molyneaux	Valley		Du	27.5	48	Sand and gravel
426	1.5 miles southeast of middle of Forksville	State Picnic Ground	do		Dr	55±	6	White sandstone
	Cherry Township							
427	Dushore	Harrington and Co.	do		Dr	311	8	Red shale
428	East end of Dushore	Sullivan Silk Co.	Canyon		Dr	152	6	do
429	1.4 miles east of Dushore	Dushore Water Co.	do		Dr	182	8	do
430	3 miles northeast of Dushore	William Rhyme	Slope		Dr	164	6	Gray sandstone
431	Mildred	W. J. Shad	do	1,850	Dr	100	6	White sandstone
432	do	Morris Hoffman	Valley	1,820	Dr	92	6	Gray sandstone
433	do	Benjamin Calaman	Slope	1,840	Dr	65	6	Gray slate
434	Bernice	Bernice Coal Co.	do	1,880	Sp			Sand
	Laporte Township							
435	Laporte	Makoma Spring Water Co.	do	1,780	Dr	256	6	Sandstone
436	do	do	Hilltop	2,040	Dr	227	6	White sandstone
437	do	do	Hillside	1,980	Sp			Sandstone
438	South end of Laporte	D. A. Kepner	Slope	1,780	Dr	86	5⅝	do
439	0.2 mile southwest of southwest corner line of Laporte	T. D. Taylor	do	1,840	Dr	85	6	Gray sandstone
440	Nordmont	Joe Little	Canyon	1,340	Dr	36	6	
	Shrewsbury Township							
441	Eagles Mere Park	W. H. Field	Upland-flat	2,000	Dr	53	6	Red shale

in Sullivan County

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	60±	—20±	S	100	N	Plant closed, open-end well.
Catskill or Chemung	20	—40±	H	5±	D	
Chemung	24	—70±	P	7±	D, S	
Pleistocene	27.5	—19.5 to —27.5	N	--------	N	Observation well, water level measured weekly by owner. See fig. 6. Goes dry in summer.
Catskill	20	—15	H	10	D	
do	39	—9	T	300	C, I	39 feet of gravel containing some water cased. Reported drawdown 15 feet pumping 200 gallons a minute. Temp. 52° F. See analysis.
do	26	—66	P	4	D, I	
do	--------	—96	T	125	P	Water soft. Reported drawdown 11 feet.
do	27	—85±	H	6	D	
Pocono	40	—40	P	4±	D	
do	66	—19	P	5	D	66 feet of sand, gravel, and clay cased.
Pottsville	10½	—14	S	5	D	Few coal streaks. Water contains some iron. Temp. 52° F. See analysis.
Pleistocene	--------	--------	F	1±	D	Temp. 54° F. Water carried by bucket to several houses.
Pocono	7	—7	T	100	P	Some water at 120 and 234 feet, main supply at bottom.
do	20	—118	P	25	P	Reported drawdown 5 feet pumping 15 gallons a minute.
do	--------	--------	F	1 to 12	P	Issues directly from outcrop of bedrock. Water reported soft.
do	33	—45±	H	4±	D	Temp. 49° F. See analysis.
do	39	—30	H	5±	D	
Catskill	24	—12	H	3±	D	Chiefly springs in Nordmont.
Pocono	52½	+4±	S	5±	D	Flows a small quantity. Water contains iron. Temp. 48° F.

Typical wells and springs

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Shrewsbury Township —Continued							
442	Eagles Mere Park	Dr. Thompson	Upland-flat	2,000	Dr	60	6	White sandstone
443	do	Forrest Inn	do	2,000	Dr	90	6	do
444	Eagles Mere	Mr. Mogaunan	Lakeshore	2,000	Dr	400		
445	do	Eagles Mere Water Co.	do	2,000	2 Dr	205	8	Gray sandstone
446	do	Brady Whitmire	Ridge	2,020	Dr	153	6	White sandstone
	Hillsgrove Township							
447	Bena Lodge (Crystal Lake)	Mr. McGloughlin	Lakeshore	1,780	Dr	40	5⅝	do
	Davidson Township							
448	Muncy Valley	J. W. Moran	Valley	860	Dr	52	5⅝	Gravel
449	Sonestown	Sonestown School	do	970	Dr	90	5⅝	do
450	1 mile southeast of Sonestown	Mr. Earle	Saddle	1,440	Dr	65	6	Red shale
451	0.6 mile northwest of Hemlock Grove	E. A. Fulmer	do	1,100	Dr	62	6	Red sandstone
452	0.7 mile northwest of Hemlock Grove	Stanley Meyers	Hillside	1,5 0 ±	Dr	155	5⅝	Red shale

[1] Dr, drilled well; Du, dug well; Sp, spring.
[2] F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated.
[3] C, cooling or condensing; D, domestic; I. industrial; N, none; P, public supply; S, stock.

in Sullivan County—Continued

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pocono	20	—30±	P	2+	D	Water contains iron.
do		—35	P	15	I	Water contains iron.
do		—	N		N	Formerly used for public supply, small yield.
do	15	—8	N	13, 56	N	Formerly used for public supply, but inadequate. See log.
do	8	—	P	4	D	
do	40	—8	S	5±	D	38 feet of sand and boulders cased. Reported tested at 20 gallons a minute.
Pleistocene	52	—22	S	4+	D	Open-end well. Tested at 50 gallons a minute. Supplies garage and 2 houses. See analysis.
do	99	—3	S	5±	D	Open-end well. Reported tested at 30 gallons a minute with small drawdown.
Catskill	3	—5	H	1	D	
do	0	—20±	H		D	Bedrock at surface. Water reported good.
do	9	—80	N	15	D	Owner will try to siphon water to lower point.

TIOGA COUNTY

[Area, 1,142 square miles. Population, 31,871]

GEOGRAPHY

Tioga County lies in the north-central part of the area, and is bordered on the north by New York State. The population is largely rural and averages about 28 inhabitants per square mile. Wellsboro, the largest borough in the county, has 3,643 inhabitants, and is followed by Elkland, with 1,978; Westfield, with 1,193; Mansfield, with 1,755, and Blossburg, with 1,696. All other boroughs have less than 1,000 inhabitants. Agriculture is the principal industry, and 58 percent of the total land area is devoted to farming, mainly dairy farming. In 1929 Tioga County ranked sixth among the 63 counties of the State in annual milk production with 15,879,899 gallons. According to the Federal census of 1929, there were 43 manufacturing establishments in the county, whose annual products were valued at a total of $14,804,926. An important discovery of deep-lying natural gas in north-central Tioga County was made in 1931. At one time oil was obtained from the Gaines oil field. Considerable coal has been mined from the Blossburg basin in Tioga County.

The topography in Tioga County is characteristic of the folded portion of the Plateaus province. Large areas of the high dissected plateau remain only along two synclinal belts of highlands trending east-northeast across the county. Broad anticlinal belts of lowlands occupy the intervening areas in the northern, middle, and southern parts. The highest point in that part of the county that has been mapped topographically is an unnamed peak on Armenia Mountain southeast of Mainesburg, which stands 2,440 feet above sea level. Pine Creek crosses the Lycoming County line at an altitude of about 830 feet, the lowest known point in the county. The maximum known relief is therefore about 1,610 feet. The maximum local relief is found where the main streams cut through the belts of highlands (plate 5C).

Tioga County lies in the Susquehanna Drainage Basin. Most of the drainage is carried to the North Branch by the Tioga and Cowanesque Rivers, the remainder being carried to the West Branch chiefly by Pine Creek but in part by Lycoming Creek.

GEOLOGY

The rock formations exposed in Tioga County range in age from the Chemung formation of Upper Devonian age to the Allegheny formation of Pennsylvanian age. The oldest rocks crop out in the 3 broad anticlinal belts mentioned above, and the youngest rocks are exposed in the Blossburg coal basin. Most of the plateau remnants are capped by the Pocono formation, with smaller remnants of the Pottsville formation.. The intermediate slopes are underlain by the Cattaraugus and Oswayo formations.

All but the southwest corner of Tioga County was covered by the Wisconsin glacier, and the entire county is believed to have been covered by the Illinoian glacier. Pronounced glacial features, such as

lakes, marshes, moraines, etc., are almost lacking in the uplands of Tioga County, as compared to the uplands of Bradford and Sullivan Counties. In the valleys, however, abundant evidence of glaciation has been preserved. The geologic history of the glacial lakes that occupied the valleys of the Tioga and Cowanesque Rivers, Marsh Creek, Crooked Creek, and upper Pine Creek, and the escape of these waters into Pine Creek, which resulted in the cutting of the deep gorge of Pine Creek (plate 5C), has been described on page 29. The lake and stream deposits filling these valleys (plate 7) and the locations of 7 prominent glacial spillways are shown in plate 2. No deposits were observed along Pine Creek below Ansonia—presumably the velocity of the water leaving the glacial lake was too great to allow deposition in this part of the creek, and the material was carried nearly to the mouth in Lycoming County.

The geologic structure in Tioga County is shown in plate 4, which shows a series of well defined folds of marked continuity trending east-northeast. According to Cathcart and Myers,[77] "Evidence of doming is observed on the Sabinsville anticline in Farmington and Lawrence townships and in Clymer Township; on the Wellsboro anticline in Elk, Delmar, Charleston, and Richmond townships; and on the Towanda anticline in Union Township. In all of the domed areas the south limb is appreciably steeper than the north. The regional plunge of the folds is to the southwest. * * * In general, the folds * * * decrease in amplitude with distance from the Allegheny Front. Surface evidence of faulting is observed on the south flank of the Sabinsville anticline in Chatham, Tioga, and Lawrence townships, on the Wellsboro anticline southeast of Wellsboro, and on the Towanda anticline in Union Township." Sub-surface faults have been noted in drilling some of the deep wells.

GROUND WATER

The glacial lake and stream deposits shown in plate 2 are unquestionably the most productive water-bearing materials in Tioga County. In most places abundant supplies of water can be obtained from sand or gravel in these deposits from properly constructed wells using screens. An example is well 458 at Westfield, which although only 78 feet deep, yields 600 gallons a minute. Some open-end wells, such as wells 473 and 474, yield as much as 400 gallons a minute. Locally, however, as at Middlebury Center, the material may be too fine for successful well development (see "remarks" for well 489). However, the use of gravel-packing sometimes produces a successful well in fine sand.

The Chemung and Catskill formations, which supply most of the rock wells, generally yield enough water for domestic needs, and supply 20 to 80 gallons a minute to some industrial wells. Well 525, which yields 184 gallons a minute, is the strongest rock well reported in the county.

The largest industrial use of ground water in Tioga County is for cooling at dairies. Records of wells at 17 different dairies are tabu-

[77] Cathcart, S. H., and Myers, T. H., Gas in Tioga County, Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. 107, pp. 14, 15, Feb. 1, 1934.

lated below. Considerable ground water is also used by tanneries at Elkland and Westfield, and for public supply as noted below.

Many of the homes at farms and villages are still supplied from dug wells, but such wells are generally falling into disfavor as they are apt to fail in dry weather and are more subject to contamination than drilled wells.

Records of 14 flowing wells are given below in the tabulated records of wells. Most of these wells flow only a small amount, but well 519 was reported to flow about 25 gallons a minute when first drilled. Most of these flowing wells are in synclines, but wells 508, in Wellsboro, are on the axis of the Wellsboro anticline. The synclinal basins are the most likely areas where other flowing wells might be expected.

The weekly water levels in an observation well (no. 495) at Gaines are shown graphically in figure 6.

Analyses of 5 samples of water from the principal water-bearing formations in Tioga County are tabulated below. Many of the Chemung waters in Tioga County are salty. No. 488 is an example of such salty waters. A few wells in the Catskill and a few in sand or gravel yield slightly salty or brackish water (analyses 483, 491), but the brackish water has probably migrated into these formations from the Chemung. A few ground waters contain undesirable amounts of iron, but the occurrence is not frequent in any of the water-bearing formations. The general quality of water to be expected from the formations in this county is summarized on pages 74, 75.

Analyses of ground waters from Tioga County

[Analyzed by E. W. Lohr. Parts per million. Numbers at heads of columns correspond to numbers in following table and in pl. 2]

Number	483	488	491	513	547
Geologic horizon	Pleistocene	Chemung	Cattaraugus	Pleistocene	Catskill
Silica (SiO_2)	—	—	—	15	—
Iron (Fe)	6.1	0.48	0.18	.07	0.10
Calcium (Ca)	75	82	56	64	26
Magnesium (Mg)	20	17	9.8	12	4.8
Sodium and potassium (Na+K)	278	1,132	183	Na 8.9 K 1.6	20
Bicarbonate (HCO_3)	263	197	170	205	110
Sulphate (SO_4)	2	7	15	46	13
Chloride (Cl)	465	1,820	300	6.5	14
Nitrate (NO_3)	.50	.0	.0	.36	4.6
Total dissolved solids	972	3,155	648	258	137
Total hardness as $CaCO_3$	270	275	180	209	85
Date of collection, 1935	Aug. 19	Aug. 19	Aug. 20	Aug. 19	Aug. 21

PUBLIC SUPPLIES

At least ten communities in Tioga County have public water supplies. Arnot, Blossburg, Gaines, and Mansfield are supplied entirely with surface water. Antrim, Elkland, Knoxville, and Westfield are supplied entirely with ground water from springs and wells. Tioga

and Wellsboro are supplied with both ground and surface water. Descriptions of the six supplies using ground water follow.

Antrim is supplied by the Fall Brook Coal Company. The main supply comes from several small springs that issue from sandstone 1.2 miles northeast of the village. Additional water when needed is pumped from a drilled well (no. 536), located near the springs. The water from both sources flows into a small reservoir whence it is distributed by gravity at a pressure of 30-35 pounds per square inch. Water is supplied without charge to 104 houses, and some water is also used for the boilers of the company. The water is not treated and is reported to be very soft.

Elkland (population 1,978) is supplied by the Elkland Borough Water Works. The principal supply comes from 12 springs in sandstone located in New York State 1.5 miles north of the borough. The water is stored in a 240,600-gallon concrete reservoir located on Mutton Hill in the northern part of the borough, and is distributed by gravity at an average pressure of about 100 pounds per square inch. Additional water when needed is pumped directly into the mains from an auxiliary drilled well (no. 472) in the northern part of the borough. It is an open-end well in gravel, is equipped with a turbine, and yields 125 gallons a minute. It was drilled in February, 1932, and previous to that three wells had been put down all of which yielded salt water. Two such wells about 150 feet deep were drilled in New York State one mile north of the borough, and one (no. 475) was drilled in gravel in the eastern part of the borough. About 500 houses are served, and in 1929 the average daily consumption was about 40,000 gallons, of which about 10 percent is used by the Elkland Leather Company (see also wells 471, 473, and 474). There are 50 fire hydrants. The water is not treated.

Knoxville (population 608) is supplied by the Knoxville Borough Water Works. The main supply comes from 6 springs, 4 of which are located back of the reservoir on a hill north of the borough, and 2 of which issue from a hill south of the borough and river. The water from the springs flows into the brick-lined reservoir, which holds 500,000 gallons, and is distributed by gravity at an average pressure of 100-110 pounds per square inch. Additional water when needed is obtained from one auxiliary drilled well (no. 460), from which water is pumped directly into the mains at a rate of 25 gallons a minute. The average daily consumption is 16,500 gallons, all of which is used for domestic purposes. There are 45 fire hydrants. The water is not treated.

Tioga (population 431) is supplied by the Tioga Water Works Company, which is owned by the borough. The main supply comes from Bentley Creek, which is dammed about half a mile east of the borough. The dam impounds more than one million gallons, and water from the reservoir flows to a 115,000-gallon concrete reservoir on a hill just east of the borough, whence it is distributed by gravity at an average pressure of 85-90 pounds per square inch. An auxiliary supply is obtained from one dug well (no. 487). The steam driven suction pump in the well pumps the water directly into the mains at the rate of 30 gallons a minute. About 132 houses are supplied, and in 1929 the

average daily consumption was about 40,000 gallons, all of which was used for domestic purposes. There are 19 fire hydrants. Chloride of lime is added to the water.

Wellsboro (population 3,643) is supplied by the Wellsboro Water Company, mainly from three streams and 13 springs, all located from 4 to 5 miles southeast of the borough. The intake on Nickel Run is in the northeast part of Duncan Township, and the intakes on Charleston Creek and McConnell Run are near the south end of Charleston Township. Mains from these sources carry the water by gravity to two earth reservoirs on a hill in the borough for gravity distribution at pressures ranging from 30 to 75 pounds per square inch. The 13 springs, each of which yields from 20 to 80 gallons a minute during normal weather, are enclosed and piped directly into the mains. Three of them are along Nickel Creek, 7 are along Charleston Creek, and the 3 Morgan springs are at Brownlee, near the well-pumping plant. The springs all went dry in 1930 and have been very low during subsequent summers. An auxiliary supply is obtained from 15 drilled wells located in a line along Charleston Creek, extending from a point 1.3 miles north of Brownlee to a point 0.6 mile south-southeast of Brownlee. Fourteen of the wells are pumped by air lift from a central compressor located at Brownlee, and one well (no. 530) at Brownlee is equipped with a force pump driven by a gasoline engine. The details and yields of these wells (520-534) are given in the well tables. Another well (511) at Round Top is no longer used (see log below). The water from the wells is pumped into the same mains that carry the stream and spring water. The average daily consumption is 400-500,000 gallons, 40 percent of which is used by the Corning Glass Works. There are 93 fire hydrants. All water is filtered and treated with chloride of lime.

Log of well of Wellsboro Water Co., at Round Top

[No. 511. Authority, Leon Wood, driller]

	Depth (feet)		Depth (feet)
Clay soil	0–8	Rock, gray	248–250
Gravel	8–11	Shale, blue	250–260
Hardpan	11–22	Rock, gray	260–270
Quicksand	22–52	Shale, blue	270–285
Sand and gravel	52–60	Rock, hard	285–340
Clay and gravel	60–93	Rock, red	340–341
Shale, blue	93–103	Shale, blue	341–351
Shale, red	103–118	Rock, hard	351–357
Shale, blue	118–158	Shale, blue	357–360
Rock, gray	158–198	Rock, hard	360–400
Shale, blue	198–248	Shale, blue	400–500

Westfield (population 1,193) is supplied by the Municipal Water Works. The main supply comes from 5 springs, which discharge by gravity into a 240,000-gallon reservoir in the south corner of the borough. The water is distributed by gravity at pressures of 80-85

pounds per square inch. The Pierce Spring, located in a canyon southeast of the borough, yields about 30 gallons a minute. The two Fairground Springs, located northeast of the borough, together yield about 15 gallons a minute. The two Seaman Springs, located about a mile west-northwest of the borough, yield respectively 35 and 75 gallons a minute. An auxiliary supply of 80 gallons a minute is pumped directly into the mains when needed from a drilled well, ending in coarse sand in the borough (no. 453), the log of which is given below. The deeper but weaker wells (no. 456) that penetrate the Chemung formation have been abandoned. The average daily consumption is about 35,000 gallons, all of which is used for domestic purposes. There are 35 fire hydrants. The water from the springs and well used is not treated, but the water from the old wells formerly used was chlorinated.

Log of well of Westfield Borough Water Dept., at Westfield

[No. 453. Authority, Pennsylvania Department of Health]

	Depth (feet)		Depth (feet)
Soil, sandy	0–18	Hardpan	39–44
Gravel, fine	18–27	Sand, fine	44–69
Sand, fine	27–39	Sand, coarse	69–78

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Westfield Township							
453	Westfield	Westfield Borough Water Department	Valley	1,370	Dr	78	8	Coarse sand
454	do	Borden Co. of Pennsylvania	do	1,370	Dr	165	8	
455	do	do	do	1,370	3 Dr	425	8	
456	do	Westfield Borough Water Department	do	1,370	3 Dr	200±	8	Shale
457	do	M. H. Renken Dairy Co.	do	1,360	2 Dr	55, 66	6	Gravel
458	do	Eberle Tanning Co.	do	1,360	Dr	78	10	Gravel and sand
	Deerfield Township							
459	Knoxville	Clinton Wood	do	1,240	Dr	116	6¼	Gray shale
460	do	Knoxville Borough Water Works	do	1,230	Dr	100±	5⅝	Gravel
461	do	Schoonover Dairy	do	1,230	Dr	88½	6	do
462	1.2 miles south southeast of Academy Corners	David Kizer	Canyon	1,340	Dr	76	6¼	Gray shale
463	1.6 miles south southeast of Academy Corners	Arch Taft	do	1,370	Dr	60	6¼	do
464	1.7 miles south southeast of Academy Corners	Hattie Merrick	do	1,380	Dr	63	6¼	Gravel
	Farmington Township							
465	0.25 mile south southeast of Farmington Center	George Van Dusen	Upland Valley	1,680	Dr	48	6¼	Gray limestone
466	1.3 miles northeast of Farmington Center	Mrs. Walter Niles	Hillside	1,760	Dr	46	6¼	Yellow shale
	Osceola Township							
467	Osceola	Mr. Crandall	Valley	1,160	Dr	160	6¼	Gravel
468	do	M. H. Renken Dairy Co.	do	1,170	Dr	200±	8	Gray shale

Tioga County

bearing bed / Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Pleistocene	78	—4	S	80	P	Open-end well. Reported drawdown 25 feet. No iron reported, hardness 110 parts per million. See log.
Chemung	80±	—	P	80±	C, I	Formerly used about 20 driven wells 18 feet deep in gravel.
do	165	—	P	50±	C, I	80 feet to bedrock, but cased 165 feet to avoid interference with well 454. Each well yields amount stated.
do	80±	—100±	N	25 to 60	N	80 feet of fine sand cased. Wells too weak for needs. Water reported slightly salty.
Pleistocene	55, 65	—2	T	200	C, I	Open-end wells. Each well yields 200 gallons a minute with 20 feet drawdown, but one well equipped with 90 gallons a minute pump. Water reported good.
do	58	—9	T	600	I	Finished with 20 feet of Johnson Everdur well screen, No. 50 slot, 11 feet, No. 80 slot, 9 feet (bottom). Drawdown after 20 hours pumping, 15 feet at 350 gallons a minute, 34 feet at 600 gallons a minute. Reported hardness of water, 300 parts per million. Have 7 old unused wells, 58 to 250 feet deep, 184-foot well yields salty water.
Chemung	57	—15±	P	16	D	Cased: Loam 9 feet, gravel 3 feet, quicksand 41 feet, clay 4 feet. Reported drawdown 12 feet. Nearby well 212 feet deep reported to yield salty water.
Pleistocene	100±	—8	S	25	P	Open-end well. Reported drawdown 2 feet.
do	88½	—11	S	4	C, I	Open-end well. Water reported good.
Chemung	73	+2	H	5±	D, S	56 feet to bedrock. Flows about ½ gallon a minute.
do	44	+	H	--------	D	Flows.
Pleistocene	63	+4	F	¼	D	Flows about ¼ gallon a minute. Reported tested at 20 gallons a minute. Water contains iron.
Chemung	20	—15	H	½	D, S	
do	16	—	H	4	D, S	
Pleistocene	160	—5	S	4	D	Open-end well. Reported drawdown 3 feet.
Chemung	100±	—90±	A	35±	C, I	Chiefly quicksand cased. Reported large drawdown.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water-
								Character of material
	Elkland Township							
469	West end of Elkland	Borden Co. of Pennsylvania	Valley	1,130	Dr	125	8	
470	do	do	do	1,130	Dr	175	8	
471	Northeast end of Elkland	Elkland Leather Co.	Slope	1,190	Dr	63	6¼	Gray sandstone
472	do	Elkland Water Co.	Valley	1,140	Dr	112	8	Gravel
473	do	Elkland Leather Co.	do	1,140	Dr	116	8	do
474	do	do	do	1,130	Dr	106	8	do
475	East end of Elkland	Elkland Water Co.	do	1,120	Dr	107	8	do
	Nelson Township							
476	Nelson	Dairymen's League Cooperative Ass'n.	Slope	1,180	Dr	500	6	Shale
	Lawrence Township							
477	1 mile south southeast of Lawrenceville	do	Valley	1,000	Dr	70	8	Gravel
	Jackson Township							
478	Jackson Summit	James Lane	Saddle	1,580	Dr	208	8	
479	0.4 mile east of Trowbridge	Ford C. Smith	Slope	1,340	Dr	94±	6	Blue shale
480	0.5 mile east northeast of Millerton	Burt Bly	do	1,180	Dr	105	5⅝	do
	Rutland Township							
481	Roseville	Harry Garrison	do	1,380	Dr	52	6	Gravel
482	do	East Smithfield Farms Co.	Valley	1,330	Dr	32	8	do
483	3.3 miles west southwest of Roseville	Leon P. Wood	do	1,260	Dr	102	6	do
	Tioga Township							
484	1 mile north of Tioga	William Capell	Slope	1,080	Dr	94	5⅝	do
485	do	Adrian West	do	1,060	Dr	90	5⅝	do
486	0.7 mile north of Tioga	Dairymen's League Cooperative Ass'n.	Valley	1,040	Dr	100	6	do
487	Tioga	Tioga Water Works Co.	do	1,050	Du	18	10	do

Tioga County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung	--------	—15±	P	30±	C, I	Water reported hard.
do	--------	—15±	P	50±	C, I	Water reported salty.
do	31	+2±	N	5	N	Flows. Water reported good, but insufficient quantity.
Pleistocene	112	—31	T	125	P	Open-end well. Reported drawdown 11 feet after 2 days pumping 250 gallons a minute. Quicksand cased. Water reported good.
do	116	—31	T	400	I	Open-end well. 116 feet of quicksand cased. Water good.
do	106	—10	T	400	N	Open-end well. 106 feet of quicksand cased, water salty. Have another good well in gravel.
do	107	—4	N	45+	N	Open-end well. Reported drawdown about 3 feet. Water reported very salty.
Chemung	--------	—	P	15	N	Reported large drawdown, poor water.
Pleistocene	70	—15±	P	50	C, I	Drilled 400 feet, very weak. Casing dynamited at 70 feet to let in water from gravel, and plugged below.
Chemung	--------	+8±	N	½	N	Abandoned milk plant. Yielded 7½ gallons a minute by pumping. Water reported good.
do	45	—12	H	3	S	
do	75	+3	S	4	D, S	Sand, gravel, clay, and quicksand cased. Flows about ½ gallon a minute, several other flowing wells nearby.
Pleistocene	52	—	H	--------	D	Open-end well.
do	32	—12±	S	75±	C, I	Open-end well. Reported small drawdown.
do	102	—1½	H	5	D	Open-end well. 80 feet of quicksand and 22 feet of gravel cased. Water contains manganese, considerable iron, hydrogen sulphide, and is slightly salty. See analysis. Temp. 52° F.
do	94	—	P	5±	D	Open-end well, 94 feet of sand cased.
do	90	—	P	10±	D, S	Open-end well, 90 feet of sand and quicksand cased.
do	100	—	N	50	N	Open-end well. Well satisfactory, plant closed.
do	18	—8	S	30	P	Curbed with stone.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Tioga Township—Continued							
488	0.7 mile south of Tioga	Sheffield Farms, Inc.	Valley	1,060	Dr	410	10–8	
	Middlebury Township							
489	Middlebury Center	Center Milk Products Co.	do	1,160	Dr	256	8	Gray sandstone
490	do	M. H. Renken Dairy Co.	do	1,160	Dr	230	6	Red shale
491	do	do	do	1,160	Dr	285	8	do
	Clymer Township							
492	Sabinsville	Ray Roberts	Slope	1,680	Dr	87	6¼	Gravel
493	0.7 mile southeast of Mixtown	Andrew Mertzsock	Ridge	2,100	Dr	63	6	Red sandstone
	Gaines Township							
494	0.3 mile west of Watrous	Norman Straitz	Valley		Dr	63	6¼	do
495	Gaines	Lewis R. Kohler	Terrace	1,290	Du	23.4		Gravel
496	do	Robert Kohler	do	1,280	Dr	93½	6	
497	do	Hunting Valley Inn	do	1,290	Dr	165	6¼	Gray sandy shale
	Shippen Township							
498	0.8 mile southwest of Ansonia	Prouty Handle Co.	Valley		Dr	560	8	Gray sandstone
499	Harrison State Park	Pennsylvania Dept. of Forests and Waters	Edge of Plateau		Dr	411	6¼	
	Delmar Township							
500	0.4 mile south of Kennedy	Frank Kennedy	Upland		Dr	87	6¼	Hard red shale
501	0.6 mile west of Stony Fork	Frank Laughton	do		Dr	100+	5⅝	Red shale
502	0.3 mile south of Draper	Ford Callahan	Hillside		Dr	120	5⅝	Gray limestone?
503	0.5 mile southeast of Sweet Briar	Earl Clark	Upland		Dr	86	5⅝	do?
504	Wellsboro	Parkview Hotel	Valley		Dr	144	6¼	Gray shale
505	do	Corning Glass Works	do		Du	15	42	Sand and gravel
506	do	Borden Co. of Pennsylvania	Slope		Dr	580	8	
507	do	do	do		Dr	215	8	

Tioga County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung	40	—20±	P	8	C	Reported drawdown 130 feet pumping 25 gallons a minute. Temp. 53° F. Water contains a little iron and is salty. See analysis.
Cattaraugus	112	—18	N	30	N	112 feet of fine sand and quicksand cased. Reported drawdown 127 feet. Water slightly salty. Abandoned because of small yield.
do	117	—20	N	3±	N	Insufficient for needs.
do	130	—20	A	10	C	30 feet from well 490. Reported drawdown 130 feet. Temp. 54° F. See analysis.
Pleistocene	87	—59	H	2	D	Fine gravel and sand, some clay, cased.
Chemung	7	—27	H	4	D	
Cattaraugus	18	—8	S	11	C	Reported drawdown 19 feet.
Pleistocene	23.4	—9 to —21	N	--------	N	Observation well. Water level measured weekly by owner. See fig. 6.
Cattaraugus	65	—	H	½	D	
do	31½	—36	P	6	D	Reported tested at 30 gallons a minute. 31½ feet of boulders cased. A nearby well 265 feet deep yields salty water.
Chemung	43	—20	N	--------	N	Abandoned oil test., 43 feet of gravel, some sand, cased. Yields salty water and some natural gas. Reported fresh water in red shale at 50 feet.
do	8	—351	--	1½	N	Insufficient supply. Original water level—333, dropped 18 feet after dynamiting, which did not increase yield. Water level measured August 20, 1935.
do	23	—56	H	2±	D, S	
do	--------	—	H	3	D	
do	16	—60	N	2	N	Water reported poor.
do	12	—4	H	3	D, S	
do	106	—18	S	6	D	Cased: gravel, 18 feet; quicksand, 88 feet; shale, 38 feet. Reported drawdown 12 feet.
Pleistocene	15	—4	N	70	N	Caisson well, steel pipe. Used only for emergency in 1931, use public supply.
Chemung	70±	—50	P	60	C	Drilled deep as test well. Water salty, causes boiler to foam.
do	70	—15	P	55	C	Water salty.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Delmar Township—Continued							
508	Wellsboro	Borden Co. of Pennsylvania	Slope		2 Dr	250	8	
509	Stokesdale Junction	New York Central Railroad	Valley	1,170	Dr	128	8	Gravel?
	Charleston Township							
510	1.3 miles northeast of Charleston	Claude L. West	Slope	1,540	Dr	88	6¼	Gray shale
511	Round Top	Wellsboro Water Co.	Valley		Dr	500	8	Blue shale
	Richmond Township							
512	2.4 miles east of East Charleston	W. R. Hubbard	do	1,370	Dr	112	5⅝	Red shale
513	Mansfield	Dairymen's League Cooperative Ass'n.	do	1,140	Dr	60	10	Gravel
514	do	do	do	1,140	Du	20	96	do
515	do	Morris Thompson	do	1,130	Dr	135	6	Blue shale
516	2 miles south of Mansfield	M. H. Renken Dairy Co.	do	1,170	Dr	60–90	8	Gravel
517	do	do	do	1,170	Dr	168	6	Shale
	Covington Township							
518	0.5 mile northwest of Covington	Fred Carlson	Slope	1,220	Dr	287	6	Blue shale
	Ward Township							
519	Chase Mills	Mr. Thomas	Valley		Dr	3,600	8–6	Gray sandstone
	Charleston Township							
520	1.3 miles north of Brownlee	Wellsboro Water Co.	do	[4]1,655	Dr	450	8	Red shale and sandstone
521	1.1 miles north of Brownlee	do	do	[4]1,680	Dr	450	8	do
	Duncan Township							
522	0.8 mile north of Brownlee	do	do	[4]1,715	Dr	450	8	do
523	0.7 mile north of Brownlee	do	do	[4]1,735	Dr	450	6	do

Tioga County—Continued

Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Chemung	70	+	P	60	C	Each well yields amount stated, each flows a small amount. Water salty. Mutual interference between wells 506-508.
Pleistocene?	128?	±	C	200	R	Reported to flow in winter, small drawdown when pumped. Probably open-end well.
Chemung	10	—6	H	7±	S	
do	93	—4	N	24	N	No water reported in drift cased. Drawdown more than 60 feet. See log.
do	100	+	F, H	10+	S	100 feet of clay and boulders cased. Reported to flow.
Pleistocene	40	—18	T	120	C, I	Finished with 20 feet of well screen. Reported drawdown 32 feet. Temp. 50° F. See analysis.
do	20	—6	--------	75	C	Used occasionally, weak in dry weather.
Chemung	75	—50	W	6±	S	Reported drawdown 50 feet. Have another well 110 feet deep, yields 15 gallons a minute.
Pleistocene	60-90	+2±	F	1+	C	Outside casing of double cased well. See well 517. Flows about 5 gallons a minute when valve first turned on, gradually reduces to one. Both casings together formerly flowed about 10 gallons a minute. Water in gravel of good quality, but slightly salty.
Chemung	--------	+	F	--------	N	Inside casing of double cased well. See well 516. Well plugged, water salty. Main supply comes from spring on hill to east.
do	122	—50±	P	2±	S	Quicksand cased.
?	354	+	F	25±	N	Abandoned oil test. Strong flow fresh water at 329 feet, said to have shot 90 feet above ground, cased off, and now flows only 25 gallons a minute between two casings. Salt water at 1,900 feet.
Catskill	20	+1	A	60	P	Well 15, 7,290 feet north of pump station. Flows small quantity.
do	40	—9	A	55	P	Well 14, 6,240 feet north of pump station. Water level measured November 28, 1934.
do	--------	—6	A	42	P	Well 13, 4,940 feet north of pump station. Water level measured in 1934.
do	35	—4	A	82	P	Well 12, 4,100 feet north of pump station. Water level measured November, 1934. Drawdown 25 feet.

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Duncan Township—Continued							
524	0.5 mile north of Brownlee	Wellsboro Water Co.	Valley	[4]1,755	Dr	403	6	Red shale, some blue
525	0.3 mile north north east of Brownlee	do	do	[4]1,785	Dr	403	6	Red sandstone and shale
526	Brownlee	do	do	[4]1,810	Dr	441	6	do
527	do	do	do	[4]1,830	Dr	451	6	Red shale and white sandstone
528	do	do	do	[4]1,825	Dr	450	6	do
529	do	do	do	[4]1,830	Dr	468	8	Gray and white sandstone
530	do	do	do	[4]1,830	Dr	50	6	Gravel
531	do	do	do	[4]1,840	Dr	230	8	White sandstone
532	do	do	do	[4]1,840	Dr	502	8–6	do
533	0.4 mile south south east of Brownlee	do	do	[4]1,860 ±	Dr	300	6	do
534	0.6 mile south south east of Brownlee	do	do	[4]1,885	Dr	561	6	Gray sandstone
535	0.3 mile south of Brownlee	New York Central Railroad	do		Dr	200±	8	White sandstone
536	1.2 miles northeast of Antrim	Fall Brook Coal Co.	Upland		Dr	92	6	Sandstone
537	Antrim	New York Central Railroad	do		Dr	203±	8	do
	Morris Township							
538	2.3 miles southwest of Morris	Eugene Campbell	do		Dr	97	5⅝	Red shale
539	Morris	Henry Campbell	Valley		Dr	35	6¼	Gravel
540	1.2 miles west of Nauvoo	J. B. Childs	Hillside	1,580	Dr	70	5⅝	Red shale
	Liberty Township							
541	1.5 miles northeast of Nauvoo	Stephen Burd	do	1,620	Dr	165	5⅝	do
542	2.4 miles west south west of Liberty	Harold Mandeville	Slope	1,650	Dr	36	6¼	Gravel
543	0.7 mile southwest of Liberty	Willard Antis	Hillside	1,760	Dr	119	6	Red shale
544	Liberty	Sarah Ostrom	Valley	1,600	Dr	101	5⅝	Hard gray shale
545	do	Mrs. Emma Keagle	do	1,560	Dr	60±	5⅝	Red shale

Tioga County—Continued

bearing bed Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill -------	40	—12	A	73	P	Well 11, 3,250 feet north of pump station.
do -------	25	—6	A	184	P	Well 10, 1,775 feet north of pump station. Best well, drawdown 12 feet.
do -------	20	—6	A	35+	P	Well 7, 775 feet north of pump station.
do -------	35	—12	A	35+	P	Well 8, 700 feet north of pump station.
do -------	20	—9	A	75	P	Well 9, 300 feet north of pump station.
do -------	-------	+ to —7	A	35	P	Well 2, at pump station. Drawdown 35 feet.
Pleistocene ----	50	—20	P	40	P	Well 1, at pump station, open-end well.
Catskill -------	-------	—10	A	14	P	Well 3, 300 feet south of pump station.
do -------	30±	—66	A	75	P	Well 4, 600 feet south of pump station. Water level measured November 28, 1934.
do -------	25	—66	A	27	P	Well 5, 1,650 feet south of pump station. Water level measured November 28, 1934.
do -------	35	—85	A	78	P	Well 6, 2,600 feet south of pump station. Water level measured November 28, 1934. Water contains iron.
do -------	-------	—	P	48±	R	May not be in use at present.
Pocono -------	-------	—26±	P	6±	P	Reported large drawdown.
do -------	-------	—	N	40±	N	Reported used only short time for emergency. Water reported to contain iron.
Catskill -------	33	—45±	H	3	D, S	
Pleistocene ----	25	—12	S	4	D	Open-end well. Reported drawdown 13 feet pumping 30 gallons a minute.
Catskill -------	22	—10±	H	4	S	
do -------	26	—65±	A	5	D, S	
Pleistocene ----	33	—9	S	4	D, S	
Catskill -------	-------	—55	H	1	D	Reported large drawdown.
do -------	20	—50±	H	5	D	
do -------	12	—35	H	2	D	

Typical wells in

No. on pl. 2	Location	Owner	Topographic situation	Altitude above sea level (feet)	Type of supply[1]	Depth of well (feet)	Diameter of well (inches)	Principal water- Character of material
	Liberty Township – Continued							
546	Liberty	Mrs. Roup	Slope	1,580	Dr	80	6	Red shale
547	do	East Smithfield Farms Co.	Valley	1,520	Dr	200	8	Red sandstone and shale
548	do	do	do	1,520	Dr	250	8	do
	Union Township							
549	0.5 mile southeast of Ogdensburg	Mr. Jones	Ridge		Dr	100±	5⅝	Red sandstone
550	1.6 miles east of Union Center	Jack Rutty	do		Dr	160	6	Red shale

[1] Dr, drilled well; Du, dug well.

[2] A, air lift; C, centrifugal pump; F, natural flow; H, lift pump, hand operated; N, none; P, force pump, power operated; S, suction pump, power operated; T, turbine; W, windmill.

[3] C, cooling or condensing; D, domestic; I, industrial; N, none; P, public supply; R, railroad; S, stock.

[4] Altitudes from Wellsboro Water Co.

Tioga County—Continued

bearing bed — Geologic horizon	Depth to which well is cased (feet)	Water level—Above (+) or below (—) surface (feet)	Method of lift[2]	Yield (gallons a minute)	Use of water[3]	Remarks
Catskill	17	.—	P	10±	D	Reported large drawdown.
do	40	—18±	P	50	C, I	Reported drawdown 42 feet pumping continuously. Temp. 50° F. See analysis.
do	40	—18±	P	50	C, I	Same drawdown as well 547. Used only in emergencies.
Catskill or Chemung	15	—15±	H	5	D	
do	10	—40	H	3	S	

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U. S. GEOLOGICAL SURVEY
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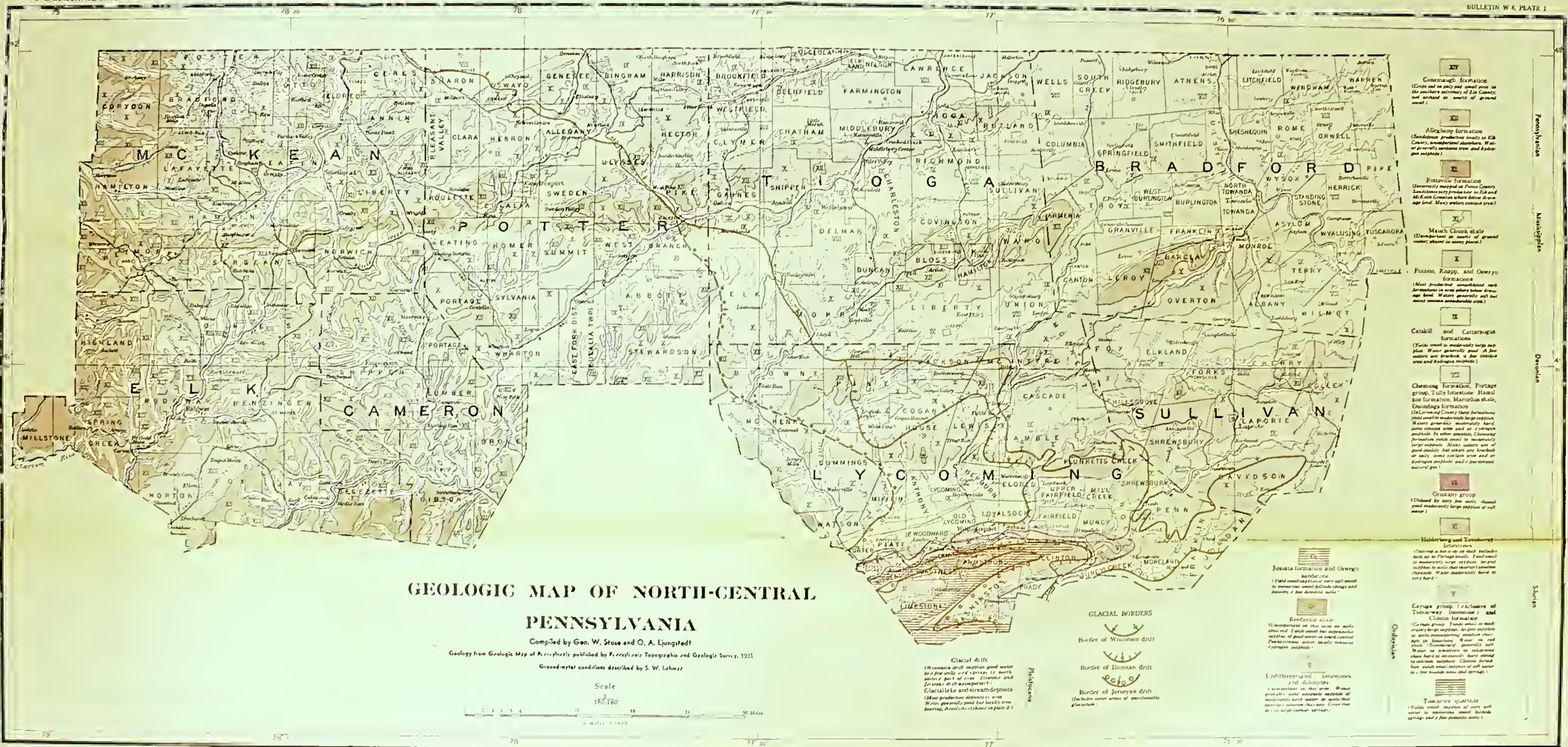
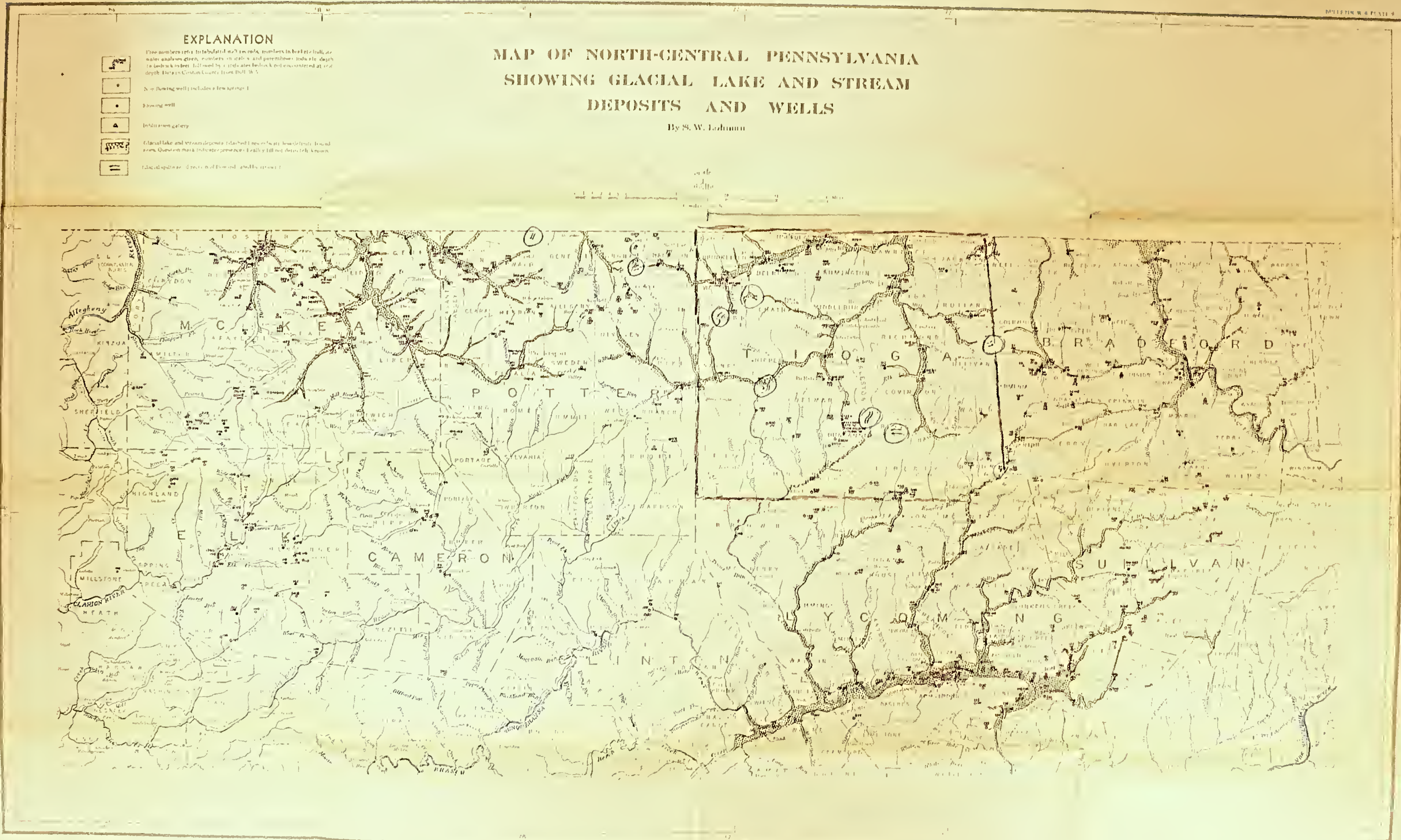
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST

BULLETIN W 6, PLATE 1




EXPLANATION
Flowing well
MAP OF NORTH-CENTRAL PENNSYLVANIA
SHOWING GLACIAL LAKE AND STREAM
DEPOSITS AND WELLS
By S. W. Lohman
M C K E A N
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